

NOTICE

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DRAFT FINAL



PHASE I RFI/RI REPORT

**WOMAN CREEK PRIORITY DRAINAGE
OPERABLE UNIT NO. 5**

**ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE, COLORADO**



APPENDIX N

Prepared For:

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado



October 1995

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Executive Summary

The Rocky Flats Environmental Technology Site (RFETS) is a former nuclear weapons fabrication facility operated by the U.S. Department of Energy (DOE), located in the Front Range of Colorado near Denver. Site activities were concentrated in an industrial area surrounded by a buffer zone of relatively undisturbed grassland that is drained by three watersheds: Walnut Creek, Woman Creek, and Rock Creek. Areas of concern associated with chemical contamination from site activities were grouped into operable units (OUs) based on the nature of the suspected contamination; each OU may have numerous individual hazardous substance sites (IHSSs). Industrial activities and IHSSs are located in the Walnut Creek and Woman Creek watersheds and may represent a potential source of contamination to downstream ecosystems. No IHSSs are located in the Rock Creek watershed.

This report presents the results of ecological risk assessments (ERAs) conducted for the Walnut Creek and Woman Creek watersheds. The ERAs represent the ecological portions of the baseline risk assessments associated with the RCRA Facility Investigation/Remedial Investigations (RFI/RI) for OUs 1, 2, 4 (in part), 5, 6, 7, 10 (in part), and 11. The combined ERA was conducted based on recent agreements among the U.S. Environmental Protection Agency (EPA), Colorado Department of Public Health and Environment (CDPHE), and DOE. ERAs were formerly planned for each OU, and preliminary field investigations were conducted on that basis. The agencies agreed that it is ecologically more appropriate to conduct the ERAs for each watershed, because this scale is more relevant to ecological receptors that are not constrained by administrative boundaries associated with the OUs.

The ecological risk assessment methodology (ERAM) for RFETS was developed to support risk management decisions for individual OUs. The approach used is consistent with a screening-level risk assessment appropriate for sites where ecological effects have not been observed, but contaminant levels have been measured and can be compared with concentrations considered protective of ecological receptors. The RFETS ERAM draws from DOE and EPA guidance and ERA tools developed at Oak Ridge National Laboratory (ORNL) and the Savannah River Site (DOE 1993a, 1993b; EPA 1992a, 1994; Norton *et al.* 1992; Opresko *et al.* 1994). The watershed ERAs includes three phases identified in EPA guidance: (1) preliminary risk calculations and problem formulation, (2) analysis, and (3) risk characterization.

Although EPA (1992a, 1994) identifies three main categories of environmental stressors (physical, chemical, and biological), chemical stressors are usually of greatest concern for ERAs conducted as part of Comprehensive Environmental Remediation, Compensation and Liability Act (CERCLA) investigations (EPA 1994). OSWER Directive 9285.2-17 states that the overall objectives of baseline ERAs for CERCLA are to (1) identify and characterize the current and potential threats to the environment from a hazardous substance release and (2) establish cleanup levels that will protect natural resources.

As noted above, preliminary field investigations were performed for each OU prior to the integration of ERAs into watersheds. However, Interagency Agreement schedules for individual RFI/RI did not allow evaluation of contaminant distribution prior to ecological field investigations. Therefore, in most cases, collection of data on specific effects of individual contaminants was not possible. As a result, the watershed ERAs focused primarily on estimation of exposure from available data on contaminant distribution in abiotic and biotic media. A large and comprehensive database was available for evaluating contaminant distribution in abiotic media. Biological tissue samples from each OU were analyzed for metals and radionuclides, and these data were used to document exposures.

The primary focus of the ERA was assessment of the potential toxicity of exposures to potential chemicals of concern (PCOCs). PCOCs are environmental contaminants identified as a result of sampling and analysis for each RFI/RI. This information was then used to identify chemicals for which exposure analysis was conducted. The analysis was conducted in two phases. A preliminary risk screen was performed for more than 150 PCOCs to identify those that were present at potentially ecotoxic concentrations (Section N3). Screening-level assumptions were adopted to minimize the chance of underestimating risk from a given PCOC. The result of the preliminary risk screen was a list of chemicals, ecological chemicals of concern (ECOCs), for which potential risk was identified.

The potential risk from exposure to ECOCs was further characterized for key receptor groups. The approach and methods for risk characterization were described in a problem formulation step (Section N4) designed to be consistent with EPA guidance on conducting ERAs (EPA 1994). However, in contrast to the EPA guidance, risk characterization was performed using existing data and toxicity information.

Risk characterization was largely conducted without the benefit of sampling and analysis specifically designed to evaluate the effects of ECOCs. However, data were available on concentrations of metals, radionuclides, and certain organic chemicals (pesticides and PCBs) in aquatic and terrestrial biota in each OU. These data were reliable indicators of exposure and collected to evaluate exposure of upper level consumers to chemicals accumulated in forage or prey (Suter 1993). Risks are summarized by watershed, receptor group, ECOC, and ERA source areas in the following subsections and in Tables ES-1 and ES-2.

Executive Summary Table 1
Summary of Ecological Risks for Walnut Creek Watershed

Receptor Group	ECOCs	ERA Source Area	Media/Exposure Point	Conclusions
Wide-Ranging Wildlife Aquatic Life	None Metals and Organics in Sediments	Not Applicable OU6 A-Ponds OU6 B-Ponds	Not Applicable Sediments	The Tier 3 ECOC screen did not identify ECOCs. Risks are primarily due to PAHs in sediments. However, no toxicity was detected in sediment toxicity tests with <i>Hyalella azteca</i> . Importance of sediment contamination is unclear but does not appear to be the primary factor controlling benthic community structure.
Aquatic-Feeding Birds	Aroclor-1254	OU6 A-Ponds OU6 B-Ponds	Pond Sediments	Aroclor-1254 concentrations in sediment exceeded risk-based criteria for ponds B-1, B-2, and B-3 only if top aquatic predators were present. Ponds currently do not support this type of community but could if pond management changed.
	Mercury	OU6 A-Ponds OU6 B-Ponds	Fish Tissue	Mercury was detected in 75% of fish from B-ponds. However, the maximum concentration was detected in B-5, which has the lowest contaminant content. The maximum HQ was 2. Mercury does not appear to represent risk to herons.
	Di-N-butyl phthalate	OU6 A-Ponds OU6 B-Ponds	Sediments	All samples with detectable DBP concentrations were "J" qualified. Only one sample corresponds to an HQ of 2; all other HQs are ≤ 1 . DBP does not appear to represent risk to herons or mallards.
Terrestrial-Feeding Raptors	Chromium	OU2 903 Pad OU2 East Trenches	Terrestrial Arthropods	Mean chromium concentration in soils was not greater than the background mean. No clear contaminant source exists. Chromium is not a risk to the kestrel population at RFETS.
	Chromium, Lead	OU4 Downgradient OU6 A-Ponds OU6 B-Ponds	Small Mammals	Chromium and lead were elevated in small mammals from pond areas. The source is unclear because soils and sediments contain low levels. Risks are possible to individual birds feeding in the area, but effects to RFETS population are minimal.
	Mercury, Vanadium	OU4 Downgradient OU6 A-Ponds OU6 B-Ponds	Small Mammals	Mercury and vanadium were detected at low frequency and some concentrations were "J" qualified. Risks appear to be minimal.
Small Mammals	Plutonium-239/240 Americium-241	OU2 903 Pad OU2 East Trenches	Soil	Radionuclides do not present significant risk to terrestrial receptors. Maximum tissue concentrations do not result in dose rates that exceed the TRV (0.1 rad/day).
	Barium	OU6 North Spray Field	Vegetation	The barium HQ of 1.05 indicates that exposures are very close to the NOAEL. Risks to small mammal populations are negligible. Some individual jumping mice might be exposed, but adverse effects would be minimal.
	Selenium	OU7 Downgradient	Vegetation	Selenium exposure exists in a small area but includes habitat for jumping mouse. The source of selenium is not clear. Levels in vegetation were twice that of background. Possible adverse effects to individuals exist, but population effects were negligible due to the small area.
Vegetation	Metals and Organics	Most Source Areas	Soils, Sediments	Nitrates in OU7 and OU4, and silver in B-ponds have the highest risk estimates. However, ecological risk is unclear because vegetation in these areas does not appear stressed.

Executive Summary Table 2
Summary of Ecological Risks for Woman Creek Watershed

Receptor Group	ECOCs	ERA Source Area	Media/Exposure Point	Conclusions
Wide-Ranging Wildlife Aquatic Life	None Metals and organics in sediments	Not Applicable OU2 903 Pad OU5 C-Ponds OU5 Old Landfill	Not Applicable Sediments	No ECOCs identified as result of Tier 3 screen. Risks are primarily due to PAHs in sediments. However, no toxicity was detected in sediment toxicity tests with <i>Hyalella azteca</i> . The importance of sediment contamination is unclear but does not appear to be the primary factor controlling benthic community structure.
Aquatic-Feeding Birds	Aroclor-1254	OU5 C-Ponds	Sediments of SID	Aroclor-1254 concentrations in sediment did not exceed risk based criteria developed for sediment at RFETS.
	Mercury	OU5 Old Landfill OU5 C-Ponds	Fish Tissue	Mercury was detected in 2 of 24 fish from C-ponds. Mercury was not detected in other fish. Risks are significant only if birds obtain all food from C-1.
	Antimony	OU5 Old Landfill	Sediments	The screening estimate assumes 100% site use. Actual use is much less because the stream supports a small fish population. Risks were not significant when adjusted for realistic site use factor.
Terrestrial-Feeding Raptors	Chromium	OU2 903 Pad OU2 East Trenches	Terrestrial Anthropods	The mean chromium concentration in soils was not greater than background mean. No clear contaminant source exists. Chromium was not a risk to the kestrel population at RFETS.
Small Mammals	Plutonium-239/240 Americium-241	OU2 903 Pad OU2 East Trenches	Soils	Radionuclides do not present significant risk to terrestrial receptors. Maximum tissue concentrations do not result in dose rates that exceed TRVs (0.1 rad/day).
Vegetation	Uranium-233/234 Uranium-238 Metals	OU5 Old Landfill Most Source Areas	Soils Soils, Sediments	See text for plutonium and americium conclusions. Soils of Ash Pits contained several metals with HQs >1. The highest HQ (7.9) was for chromium. Ecological risk to vegetation communities is minimal because each of the Ash Pits involves relatively small areas.
				Sediments of C-ponds contain mercury at concentrations that exceed TRVs for wetland vegetation. However, growth of vegetation in littoral zone appears normal.

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List of Acronyms

AQUIRE	Aquatic Information Retrieval
AWQC	ambient water quality criteria
BCF	bioconcentration factor
BDL	below detection limit
BSF	bioconcentration sediment factor
BTAG	Biological Technical Assistance Group
bw	body weight
CDPHE	Colorado Department of Public Health and Environment
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	chemical of concern
CRDL	contract-required detection limit
CWQCC	Colorado Water Quality Control Commission
DBP	di-N-butyl phthalate
DOE	U.S. Department of Energy
DQO	data quality objective
EcMP	Ecological Monitoring Program
ECOC	ecological chemical of concern
EEC	environmental effects criteria
EMD	Environmental Management Department
EPA	U.S. Environmental Protection Agency
EPM	exposure pathway model
EqP	equilibrium partitioning

ERA	ecological risk assessment
ERAM	ecological risk assessment methodology
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
ha	hectares
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IA	industrial area
IAEA	International Atomic Energy Agency
IAG	Interagency Agreement
IDL	instrument detection limit
IHSS	individual hazardous substance site
IRIS	Integrated Risk Information System
ISQC	interim sediment quality criteria
ITS	interceptor trench system
LOAEL	lowest observed adverse effect level
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDL	method detection limit
mph	miles per hour
NCP	National Contingency Plan
NOAEL	No Observed Adverse Effects Level
ORNL	Oak Ridge National Laboratory
OU	operable unit
PA	protected area

PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCOC	potential chemical of concern
PD	percent dissimilarity
pdf	probability density function
PMJM	Preble's meadow jumping mouse
PU&D	property utilization and disposal
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RFEDS	Rocky Flats Environmental Database System
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA facility investigation/remedial investigation
RI/FS	remedial investigation/feasibility study
SCM	sitewide conceptual model
SDWA	Safe Drinking Water Act
SID	south interceptor ditch
SQB	sediment quality benchmark
SUF	site use factor
SVOC	semivolatile organic compound
TA	terrestrial arthropod
TAL	target analyte list
TEF	toxicity equivalency factor
TIC	tentatively identified compound
TM	technical memoranda
TRV	toxicity reference value

TV	tolerance value
UCL ₉₅	95 percent upper confidence limit
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compound
WQS	water quality standard

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N1. Overview of Ecological Risk Assessments at Rocky Flats Environmental Technology Site

The Rocky Flats Environmental Technology Site (RFETS) is a former nuclear weapons fabrication facility operated by the U.S. Department of Energy (DOE), located in the Front Range of Colorado near Denver (Figure N1-1). Site activities were concentrated in an industrial area surrounded by a buffer zone of relatively undisturbed grassland that is drained by three watersheds: Walnut Creek, Woman Creek, and Rock Creek (Figure N1-2). Areas of concern associated with chemical contamination from site activities were grouped into operable units (OUs) based on the nature of the suspected contamination (Figure N1-2). Each OU may have numerous individual hazardous substance sites (IHSSs). Industrial activities and IHSSs are located in the Walnut Creek and Woman Creek watersheds and may represent a potential source of contamination to downstream ecosystems (Figure N1-3). No IHSSs are located in the Rock Creek watershed.

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The agencies agreed that it is ecologically more appropriate to conduct the ERAs for each watershed, because this scale is more relevant to ecological receptors which are not constrained by administrative boundaries associated with the OUs. ERAs are now required for four areas; (1) the industrial area/protected area (IA/PA); (2) the Walnut Creek watershed; (3) the Woman Creek watershed; and (4) offsite areas including Great Western Reservoir, Standley Lake, and Mower Reservoir.

N1.1 Regulatory Compliance Objectives

An ERA is required to support the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Record of Decision or the Resource Conservation and Recovery Act (RCRA) Corrective Action Decision for any of the OUs within these areas.

Sections within CERCLA include statements that both human health and the environment must be considered when assessing risks associated with releases from hazardous waste sites. Also, the National Contingency Plan (NCP) specifically states that an environmental evaluation must be performed to assess threats to the environment (40 CFR Part 300.430 [e][2][i][G]) during the overall process of assessing the need to remediate a hazardous waste site. The Interagency Agreement (IAG) among DOE, EPA, and CDPHE states that one objective of the RFI/RI is to provide data to establish the baseline risk assessment for human health and the environment for the OU. The methodology used here evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more chemical stressors (EPA 1992a).

Risk managers at Superfund sites such as RFETS make decisions about the need for, and level of, remediation of contaminated sites based on the results of both human health risk assessments (HHRAs) and ERAs. This appendix presents the results of the ERAs for the Walnut Creek and Woman Creek watersheds and includes risks from exposure to contaminated environmental media, including water, sediments, soils, and biological tissues.

N1.2 ERA Approach

The ecological risk assessment methodology (ERAM) for RFETS was developed to support risk management decisions for individual OUs. The approach used is consistent with a screening-level risk assessment appropriate for sites where ecological effects have not been observed, but contaminant levels have been measured and can be compared with concentrations considered protective of ecological receptors. The RFETS ERAM draws from DOE and EPA guidance and ERA tools developed at Oak Ridge National Laboratory (ORNL) and the Savannah River Site (DOE 1993a, 1993b; EPA 1992a, 1994; Norton *et al.* 1992; Opresko *et al.* 1994).

Although EPA (1992a, 1994) identifies three main categories of environmental stressors (physical, chemical, and biological), chemical stressors are usually of greatest concern for ERAs conducted as part of CERCLA investigations (EPA 1994). OSWER Directive 9285.2-17 states that the overall objectives of baseline ERAs for CERCLA are (1) to identify and characterize the current and potential threats to the environment from a hazardous substance release and (2) establish cleanup levels that will protect natural resources.

As noted above, preliminary field investigations were performed for each OU prior to the integration of ERAs into watersheds. However, IAG schedules for individual RFI/RI did not allow evaluation of contaminant distribution prior to ecological

field investigations. Therefore, in most cases collection of data on specific effects of individual contaminants was not possible. As a result, the watershed ERAs focused primarily on estimation of exposure from available data on contaminant distribution in abiotic and biotic media. A large and comprehensive database was available for evaluating contaminant distribution in abiotic media. Biological tissue samples from each OU were analyzed for metals and radionuclides and these data were used to document exposures.

N1.3 Sitewide ERA Methodology

To complete the four RFETS ERAs, DOE is following recent EPA guidance (EPA 1992a, 1994). Each ERA was performed in three major phases: (1) problem formulation, (2) analysis, and (3) risk characterization.

Problem formulation is the process that establishes the specific goals and focus of the ERA. It consists of (1) developing a conceptual model of contaminant sources, release mechanisms, transport mechanisms, receptors, exposure points, and habitat types, (2) identifying ecological chemicals of concern (ECOCs), and (3) identifying the environmental or assessment endpoints to be protected.

In the analysis phase, field studies are conducted as designed in the problem formulation, environmental exposure is assessed using these data, and measured or modeled effects are characterized. The exposure assessment describes the magnitude and spatial and temporal patterns of exposure to ecological receptors.

Risk characterization integrates the exposure assessment and the effects assessment. It includes a description of risk in terms of the assessment endpoints, a discussion of the ecological significance of the effects, a summary of the overall confidence in the ERA, and a discussion of possible risk management strategies.

N1.3.1 Documentation of the ERA

The ERAM includes three technical memoranda (TMs) that summarize the general approach and methods used in ERAs at RFETS. A summary of the TMs is presented in the following subsections.

N1.3.2 TM1—Assessment Endpoints

TM1 describes the general technical approach and scope of the ERAs, and presents the assessment endpoints (Suter 1989, EPA 1994), which are the focus of data collection and analysis for ERAs at RFETS. TM1 also describes the overall process for conducting ERAs at RFETS and the role of each TM in the process.

N1.3.3 TM2—Sitewide Conceptual Model

An important component of the ERA process is the establishment of the relationship between the key components of the RFETS ecosystem (DOE 1995a). The following information was included in TM2:

- Descriptions of the key ecological features of RFETS, including vegetation, wildlife, aquatic organisms, and protected species
- Summaries of existing sitewide monitoring programs
- RFETS exposure pathway models, which describe the contaminant transport and exposure mechanisms important in evaluating exposure of ecological receptors to the chemical stressors at RFETS
- Selection criteria for the identification of key ecological receptors
- General exposure parameters for key receptor species

N1.3.4 TM3—Ecological COCs Screening Methodology

The objective of TM3, the ECOC screening methodology, was to describe the process by which ECOCs are identified (DOE 1995b). The selection process requires that judgments be made about the appropriate level of protectiveness for the ecological receptors at RFETS. Application of the screening process results in a list of ECOCs, which are the focus of subsequent detailed exposure and effects analysis and risk characterization.

The RFETS ecological screening methodology used a phased approach with increasingly detailed analyses conducted in three tiers. Tier 1 consisted of identifying chemicals detected within each source area that were above background concentrations. This was done using a statistical methodology developed specifically for RFETS. The aggregation of data by contaminant source area required the establishment of a sitewide database so data could be aggregated regardless of OU boundaries. Prior to this effort, all data were segregated by OU. The result of Tier 1 was a list of PCOCs that was further screened in Tier 2 and Tier 3 using ecotoxicity criteria. Tier 2 and Tier 3 screens each required estimates of exposure for the key ecological receptors at RFETS. Methods used in Tiers 1, 2, and 3 are explained in detail in Section N3.

TM2 (DOE 1995a) and TM3 (DOE 1995b) provide the foundation of the ERA technical program. The ERA for watersheds was conducted using the information and the methods described in these two documents.

N1.4 Risk Screen and Characterization

The screening-level risk assessment method developed for RFETS requires the comparison of site analytical data to screening-level ecotoxicological benchmarks to determine which PCOCs are present at potentially toxic levels and should be considered as ECOCs for ERAs. More than 150 potential chemicals of concern (PCOCs) including metals, organic compounds, and radionuclides were identified as a result of the RFI/RIs.

Ecotoxicological benchmarks were developed for each of the PCOCs and compared to concentrations detected in environmental media. Assistance in identifying benchmarks was solicited from other sites in the DOE complex and associated academic institutions. Site-specific ecotoxicological benchmarks were derived using methods developed at Oak Ridge National Laboratories (ORNL) (Opresko *et al.* 1994). Toxicologists from Clemson University and radioecologists from Oregon State University and Argonne National Laboratory conducted extensive literature searches for the remaining PCOCs and developed preliminary benchmarks. Life history information on representative species found at RFETS was obtained from EPA (1993) or scientific literature and documented by DOE (1995a).

Although cumulative risks from all defined contaminant source areas within a watershed can be estimated, this assessment is not comprehensive. The ecological risk associated with potential future effects of contaminated groundwater, should it emerge to surface water, is not evaluated in this ERA, but is deferred to a separate evaluation of sitewide groundwater. The ecological risks associated with sources in the IA OUs will also be evaluated in a separate assessment. Results of this assessment can, however, be used by risk managers to make decisions on whether or not current ecological risks influence cleanup of the IHSSs within the OUs listed above.

N1.5 Document Organization

This ERA report for the two watersheds consists of a summary of the field investigation results, the analysis phase, and the risk characterization phase. To save time and limit funds, this ERA also includes documentation of the problem formulation.

Section N2 provides a description of the site and the conceptual model used to evaluate risks of exposure to ecological receptors at RFETS. The physical and ecological setting of the site is described in Section N2.1, the distribution of contaminants at the site is summarized in Section N2.2, and areas potentially affected by site contaminants are described in Section N2.3. The conceptual model

presented in Section N2.4 identifies contaminant sources, release mechanisms, transport pathways, exposure routes, abiotic and biotic exposure points, and ecological receptors present at RFETS.

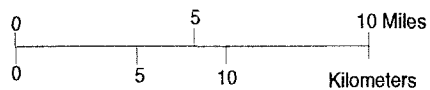
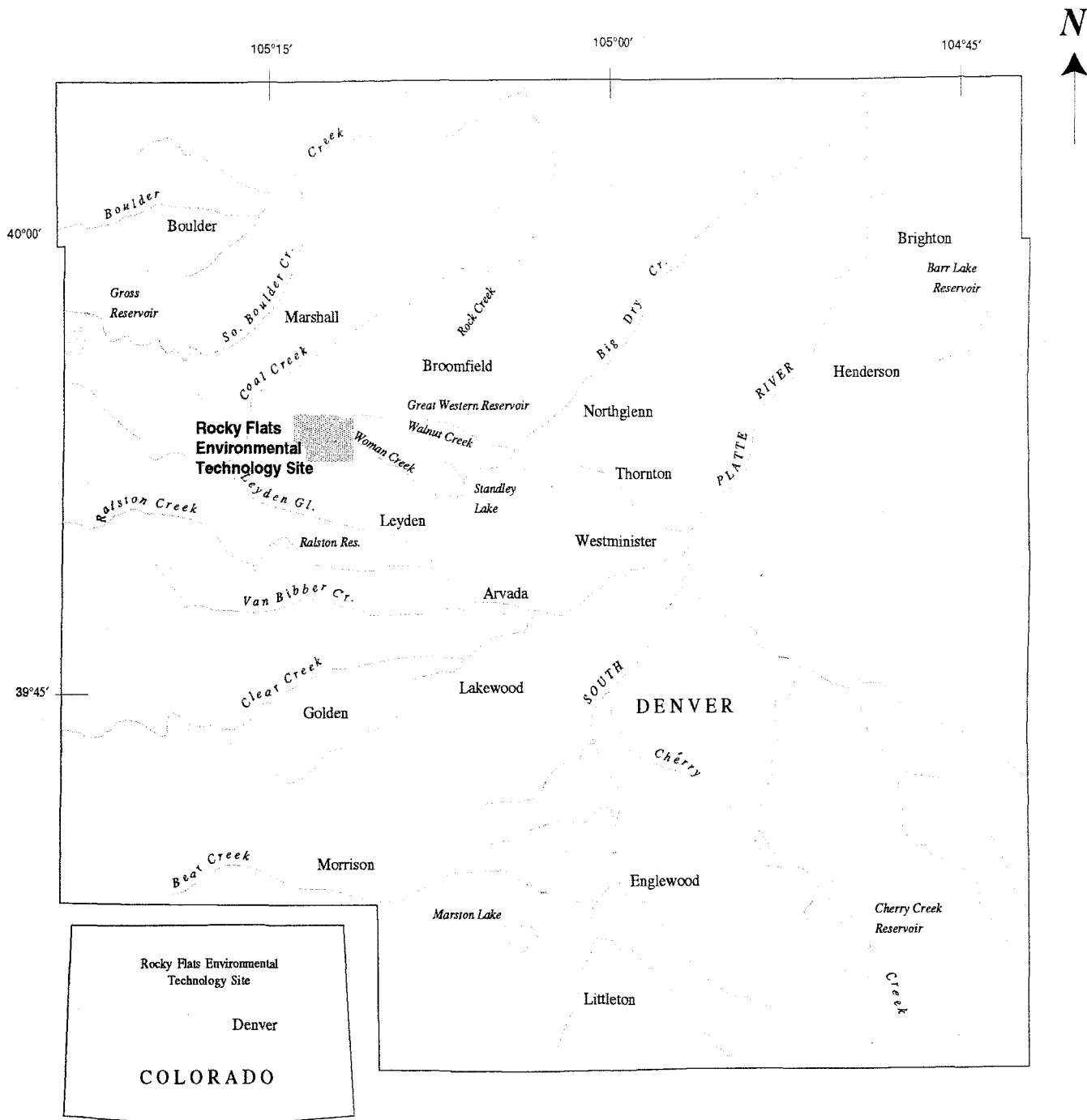
Section N3 provides the preliminary exposure and risk calculation. Approach and methods are described in N3.1, and results are summarized in Section N3.3. The preliminary risk screen resulted in a large amount of data which, for practical reasons, are presented in Attachments 5 and 6.

Section N4 describes the problem formulation based on results of the ECOC screen presented in Section N3. Assessment endpoints and specific objectives were developed for evaluating risk to six classes of ecological receptors. In addition, a separate analysis of potential radionuclide effects is provided.

Section N5 presents specific methods and results of the risk characterization. Conclusions are presented in Section N6.

CHAPTER N1

FIGURES



U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

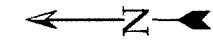
ERAs for Woman Creek and Walnut Creek
Watersheds at RFETS

**Location of Rocky Flats
Environmental Technology Site**

September 1995

Figure N1-1

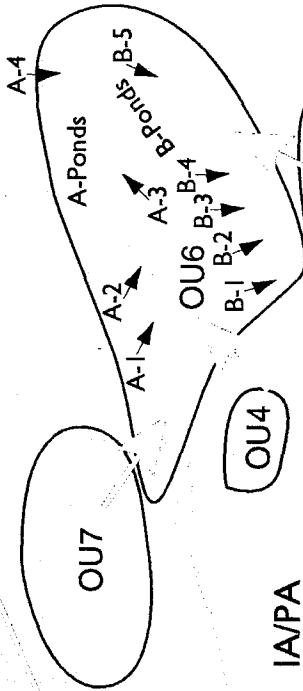
Rock Creek Watershed



Rock Creek

Walnut Creek Watershed

Walnut Creek A-5



Offsite Areas

Mower Reservoir

Woman Creek Reservoir

Mower Diversion Ditch

South Interceptor Ditch

Woman Creek

Pond C-1

Pond C-2

Smart Ditch

Pond D-1

Pond D-2

Antelope Springs

Woman Creek Watershed

LEGEND	
	Impoundments
	Streams and Ditches
	Approximate Location of Operable Units
	General Direction of Contaminant Movement
	Watershed Boundaries
	RFETS Boundary

U.S. DEPARTMENT OF ENERGY Rocky Flats Environmental Technology Site Golden, Colorado	
ERAs for Woman Creek and Walnut Creek Watersheds at RFETS	
Relationship Between Watersheds, Operable Units, and Contaminant Movement	
September 1995	Figure N1-3

N2. Site Description and Conceptual Model

This section provides a general site description of RFETS, summarizes the distribution of environmental contaminants, and describes the potential pathways by which ecological receptors may be exposed to site contaminants. Physical and ecological characteristics, including protected species, are presented, followed by a general description of the distribution of contaminants and the areas they potentially affect. The conceptual model summarizes abiotic and biotic exposure points, exposure pathways, and ecological receptors used in the risk assessment.

N2.1 Physical and Ecological Setting

This section summarizes information on the physical and ecological characteristics at RFETS that has been presented in greater detail in other documents. An overview of site climate, geology/soils, and groundwater is provided in Sections N2.1.1 through N2.1.3. Descriptions of surface hydrology/topography and ecology are provided for each of the three main watersheds at RFETS in Sections N2.1.4 and N2.1.5.

N2.1.1 Climate

The climate at RFETS is highly continental and semi-arid. Mean annual precipitation is approximately 18 inches, based on 20-year means for Boulder and Lakewood, Colorado (NOAA 1994). Temperatures in the RFETS region exhibit large diurnal and annual ranges but are generally moderate. Average minimum and maximum temperatures, based on 20-year means for Boulder and Lakewood, Colorado, are approximately 19°F and 42°F in January and 59°F and 88°F in July (NOAA 1994).

RFETS is noted for its strong northwesterly winds, although wind speeds under 15 miles per hour (mph) represent the average conditions. The windstorm season at RFETS extends from late November into April; the strongest winds usually occur in January. Commonly recorded wind speeds at the site exceed 75 mph; gusts exceeding 100 mph are experienced every three to four years.

N2.1.2 Geology and Soils

RFETS is located on the western margin of the Colorado Piedmont section of the Great Plains Physiographic Province (Thornbury 1965, Hunt 1967). The Colorado Piedmont is an area of dissected topography reflecting folding and faulting of bedrock along the edge of the Front Range uplift, subsequent fluvial processes, and

more recent incision of drainages and removal of portions of the alluvial cap. RFETS occupies the eastern edge of the Rocky Flats pediment.

N2.1.2.1 Surficial Geology

Surficial deposits at RFETS range in thickness from 0 to more than 100 feet and include artificial fill and colluvial, landslide, and alluvial deposits. Figure N2-1 illustrates the lateral distribution of these deposits across the site. Areas where artificial fills are present include road and railroad embankments, earthen dams, landfills, and spoil piles along some of the irrigation ditches. Colluvial deposits cover the steep slopes in the incised stream drainages. Alluvial deposits occur in flood plains, stream channels, and terraces along the drainages across RFETS. Characteristics of surficial deposits are thoroughly described in USGS (1994) and EG&G (1995a).

N2.1.2.2 Bedrock Geology

The Rocky Flats Alluvium is unconformably underlain by (from youngest to oldest) the Arapahoe Formation, Laramie Formation, Fox Hills Sandstone, and Pierre Shale, all deposited during the Late Cretaceous. The Arapahoe Formation is 0 to 50 feet thick beneath RFETS and consists of fluvial claystone and silty claystone interbedded with discontinuous fluvial sandstone units. The underlying Laramie Formation, which is 600 to 800 feet thick at the site, represents a deltaic environment. The Fox Hills Sandstone comprises 90 to 140 feet of friable, fine-grained sandstone with interbedded sandy shales characteristic of near-shore marine deposits. The basal unit of the Fox Hills Sandstone interfingers with the Pierre Shale, which consists of approximately 8,000 feet of marine deposits. The Geologic Characterization Report (EG&G 1995a) contains a complete description of the bedrock geology of RFETS.

N2.1.2.3 Soils

As is typical throughout the region, soils at RFETS are strongly influenced by the deposits on which they have formed. In general, soil textures at RFETS are predominantly loamy with varying amounts of clay, sand, gravel, and cobbles. The lateral distribution of soils across the site is illustrated on Figure N2-2. The most laterally extensive soils at the site are cobbly and gravelly soils of the Flatirons-Veldkamp series. These deep, well-drained soils occupy pediment surfaces, high terraces, and upper hillsides and are formed in stony to gravelly and loamy material of the Rocky Flats Alluvium (Price and Amen 1983). Surface soil nutrient content and physical parameters such as texture and moisture holding capacity are described in the Ecological Monitoring Program (EcMP) 1995 Annual Report (DOE 1995c).

N2.1.3 Groundwater

Groundwater at RFETS occurs in Quaternary surficial materials (Rocky Flats Alluvium, colluvium, and valley-fill alluvium) and in underlying Cretaceous sedimentary bedrock (claystones, siltstones, sandstones). Groundwater present in surficial materials and the upper weathered section of bedrock units is generally under unconfined conditions. Groundwater present in bedrock aquifers beneath the upper weathered section may be under either confined or unconfined conditions. The Hydrogeologic Characterization Report (EG&G 1995b) contains a complete description of the hydrogeology of the geologic units underlying the site.

N2.1.4 Surface Hydrology

Three intermittent or ephemeral streams drain RFETS: Rock Creek, Walnut Creek, and Woman Creek (Figures N1-2 and N1-3). Rock Creek drains the northern portion of the site and flows northeastward toward its confluence with Coal Creek. Rock Creek is located outside the historic influence of RFETS activities and is considered to be unaffected by the facility. Walnut Creek and Woman Creek flow eastward across the central and southern portions of the site, respectively. Because part of the Walnut Creek and Woman Creek watersheds have historically been influenced by production and waste disposal activities at RFETS, they represent potential pathways for transport of contaminants and exposure to onsite and offsite receptors. Water flow in the Walnut Creek and Woman Creek watersheds has been historically managed for irrigation and offsite water storage and more recently for RFETS-related water and sediment management. Flow has often been diverted within and among drainages, altering natural flow patterns.

N2.1.4.1 Walnut Creek

Walnut Creek, which drains most of the industrial area, has three major branches: South Walnut Creek, North Walnut Creek, and an unnamed tributary locally referred to as No Name Gulch (Figure N2-3). Walnut Creek currently terminates in the Broomfield Diversion Canal; the creek previously flowed into Great Western Reservoir approximately 1 mile east of the site. The stream is typically dry during much of the late summer, fall, and winter, especially in segments east of the site (EG&G 1993a, 1994a).

The topography and hydrology of Walnut Creek vary considerably throughout the watershed. The western portion of the basin has low relief, a gradient of approximately 2 percent, and high infiltration rates. The central portion of the basin has well-developed channels with sideslopes of up to 20 percent, a gradient of 4 percent, and finer soils. The eastern portion of the basin is characterized by the

return to a lower gradient (2 percent), broad valley floors with shallow sideslopes of about 5 percent, and low to moderate infiltration rates.

The three branches of Walnut Creek have been greatly modified by diversion, channelization, construction of detention ponds, and placement of fill material. Four detention ponds have been constructed on North Walnut Creek (A-ponds); and five have been constructed on South Walnut Creek (B-ponds) as part of the runoff control and pollution prevention programs at RFETS. Although the ponds lie along the drainages, water does not sequentially flow from each pond to the next downstream. Flow has been diverted within the pond series to provide flood control and sediment retention for the site (DOE 1995a). Water is released from the terminal ponds (Pond A-4 and Pond B-5) as needed to manage water levels. As a result, regular flow does not occur in the northern and southern branches. The No Name Gulch drainage contains the East Landfill Pond. Flow in this ephemeral tributary is highly dependent on local runoff and groundwater recharge. No regular flow from the East Landfill Pond currently exists.

N2.1.4.2 Woman Creek

This east-flowing stream system drains the southern portion of RFETS and extends eastward to Standley Lake. The western portion of Woman Creek is characterized by shallow or indistinct channels, a low gradient, and high infiltration rates. The central portion is more incised and has both steeper gradients and steeper sideslopes. The eastern portion occupies a broad, gently sloping valley. Soils in the central and eastern reaches of the basin have low infiltration rates. As with Walnut Creek, flows are typically highest in the spring, and much of the stream channel is dry during late summer, fall, and winter.

Currently, Woman Creek is diverted via the Mower Ditch into Mower Reservoir east of Indiana Street. Water that is not collected in Mower Ditch, or that overflows the diversion, drains back into Woman Creek (Figures N1-3 and N2-4). Two detention ponds (Pond C-1 and Pond C-2) have been constructed within the historic Woman Creek watershed. Pond C-1 is fed directly by the mainstream of Woman Creek. Woman Creek is diverted around Pond C-2 and feeds both Mower Ditch and lower sections of Woman Creek. At present, the main source of water in Pond C-2 is the south interceptor ditch (SID), which intercepts runoff from the industrial complex. TM2 (DOE 1995a) contains a more complete description of water flow in the C-ponds.

The drainage to the south of Woman Creek, known as Smart Ditch, historically was an ephemeral tributary that joined Woman Creek just west of Indiana Street. Smart Ditch flows through Pond D-1 and Pond D-2, which are not part of the main

drainage, RFETS runoff control, or pollution prevention system. Therefore, Smart Ditch is not part of Woman Creek for evaluation in the watershed ERA. Pond D-1 and Pond D-2 may be used as potential reference ponds for evaluation of the effects of contaminants versus the influence of pond management on measurement endpoints.

N2.1.5 Ecological Setting

RFETS is located just below the elevation at which plains grasslands grade abruptly into lower montane (foothills) forests. The topographic diversity, and associated differences in substrate and microclimate, found in this transition zone are reflected in a mosaic of plant and animal communities.

A complete list of vegetation, mammals, birds, reptiles, and fish occurring onsite can be found in Environmental Management Department (EMD) Operating Procedures 5-21200-OPS-EE (EG&G 1994b). A more quantitative description of many of the habitats can be found in the Ecological Monitoring Program (EcMP) 1995 Annual Report (DOE 1995c). The following sections summarize the terrestrial and aquatic communities found within the three main watersheds, which are described in greater detail in TM2 (DOE 1995a).

N2.1.5.1 Vegetation

The present vegetation at the site is dominated by a mixed prairie ecosystem, with riparian and wetland communities occurring along some drainages, ponds, and seeps. Some areas show lingering effects of prior grazing, and other areas clearly reflect the prolonged absence of use by domestic livestock. A relatively small percentage of the area outside the industrial complex is disturbed ground associated with various historic or ongoing activities. Most of the upland surfaces and gentle hillsides support a mixture of native grasses, forbs (broadleaf herbaceous species), and shrubs. The distribution of habitat (vegetation) types at the site is shown on Figure N2-5.

Relatively mesic (moist) sites compose 77 percent of the total area at RFETS. These sites often support stands of midgrasses and, in particularly moist or undisturbed sites, tallgrasses. The relatively mesic conditions of the site reflect the greater soil moisture associated with movement of water through the coarse Rocky Flats Alluvium that caps the pediment surface. Areas of tallgrass prairie are particularly limited in the region because of extensive agriculture or development; small remnant communities are present in piedmont areas in the northwestern corner of the site.

Relatively xeric (dry) sites compose 18 percent of the total area at RFETS. These sites differ from the mesic grasslands primarily in having shorter and sparser cover, occasionally dominated by species typical of shortgrass prairie, and xeric sites generally supporting fewer plant and animal species. Because drier areas are slower to recover from disturbance, some of the xeric sites contain substantial amounts of weedy annual grasses and forbs. *Yucca* and cacti are conspicuous in areas of historically heavy grazing and on shallow, rocky soils.

Relatively hydric (wet) sites supporting wetland and riparian communities compose 5 percent of the total area at RFETS (DOE 1994a). These wetland and riparian communities are, for the most part, linearly aligned along Walnut Creek and Woman Creek, although they also occur in areas fed by seeps. The most extensive wetlands occur in an area south of Woman Creek known as Antelope Springs, along the northern portion of Pond C-1, between the A-ponds, and on the hillsides to the southwest of the B-ponds (Figure N2-6). Wetland and riparian habitats are of particular concern for the ERAs for Walnut Creek and Woman Creek watersheds for three reasons: (1) the vegetation and seasonal availability of surface water characteristic of wetlands and riparian areas attract wildlife not associated with prairie habitat; (2) wetlands and riparian areas provide valuable resources such as water, food, shelter, and nesting areas for wildlife that inhabit surrounding areas; and (3) wetlands are dependent on the presence of surface water, an important consideration given the water management practices at RFETS.

N2.1.5.2 Wildlife

As in most of the Front Range Urban Corridor, the wildlife of RFETS has been greatly influenced by the increase in human use and disturbance over the past 100 years. Most notable have been reductions in the number and diversity of ungulates (hoofed mammals) and large predators. However, the habitat diversity of RFETS, coupled with protection from grazing and human disturbance across most of the site, have resulted in a relatively rich animal community. Annual monitoring reports provide detailed information on species occurrence, relative abundance, and habitat use (DOE 1993c, 1994b, 1995c), as does TM2 (DOE 1995a). Wildlife species typically found at RFETS are briefly described below. To enhance readability of the report, only common names are used.

Large mammals commonly observed at RFETS include mule deer and predators such as the coyote and red fox. Small mammals occurring at the site include a variety of rodent, shrew, and lagomorph species. The deer mouse and prairie vole are among the most common small mammals at the site. The small mammal community supports several raptor species such as the American kestrel, red-tailed hawk, and great horned owl. Small birds associated with different vegetation

communities at RFETS provide prey for raptors and other predators. The most extensive avian communities on the site are dominated by ground-nesting species typical of prairie ecosystems in the region. Wetland and riparian areas support mammals such as the raccoon, muskrat, and meadow vole, as well as a variety of waterfowl and wading birds such as the mallard and great blue heron. Amphibians such as the tiger salamander, northern chorus frog, and northern leopard frog are also found onsite.

N2.1.5.3 Aquatic Habitats and Organisms

Although aquatic habitats are limited in both variety and areal extent, they tend to serve as potentially important exposure pathways to ecological receptors for three reasons: (1) surface water and shallow groundwater are important transport mechanisms at RFETS, (2) chemical exposure to aquatic organisms is often intensified by prolonged contact and direct uptake from the surrounding medium (water and sediment) as well as trophic uptake (Section N2.4.4), and (3) water is a limited resource in prairie ecosystems and thus tends to receive concentrated use.

The tendency of many of the ponds and most stream reaches to periodically become dry makes these habitats unsuitable for aquatic organisms that require permanent water. Even organisms adapted to seasonally dry sites may be precluded by the unpredictability of water quantity relative to specific life cycles. In ponds that do not become completely dry, the fluctuations in water levels inhibit the establishment of a productive littoral (shoreline) zone. Water management practices at RFETS further alter seasonal fluctuations in water levels.

N2.1.5.4 Protected Species

A variety of protected species have been documented at RFETS, and additional protected species are potentially present. Protected species include plants or animals that are federally listed as threatened or endangered, candidates for listing as threatened or endangered, or Colorado species of special concern (CDOW 1994; USFWS 1994a, 1994b, 1995; DOE 1995a). The following protected species are present or potentially occur within the RFETS vicinity:

Federally Listed Endangered Species

- Peregrine falcon (*Falco peregrinus*) (State Listed Threatened)
- Black-footed ferret (*Mustela nigripes*)

Federally Listed Threatened Species

- Bald eagle (*Haliaeetus leucocephalus*)
- Ute ladies-tresses (*Spiranthes diluvialis*)

Category 1 Candidate for Federal Listing

- Colorado butterfly plant (*Gaura neomexicana coloradensis*)

Category 2 Candidates for Federal Listing

- White-faced ibis (*Plegadis chihi*)
- Mountain plover (*Charadrius montanus*)
- Ferruginous hawk (*Buteo regalis*)
- Northern goshawk (*Accipiter gentilis*)
- Loggerhead shrike (*Lanius ludovicianus*)
- Baird's sparrow (*Ammodramus bairdii*)
- Preble's meadow jumping mouse (*Zapus hudsonius prebleii*)
- Swift fox (*Vulpes velox*)

Category 3 (no longer a candidate for federal listing)

- Long-billed curlew (*Numenius americanus*)

Colorado Species of Special Concern

- American white pelican (*Pelecanus erythrorhynchos*)
- Burrowing owl (*Athene cunicularia*)
- Forktip three-awn (*Aristida basiramea*)
- Toothcup (*Rotala ramosior*)

Details concerning the status and distribution of protected species that occur or potentially occur at RFETS are provided in TM2 (DOE 1995a).

One federally listed endangered bird species, the peregrine falcon, has been observed at RFETS. Peregrine falcons have nested on rock formations southwest of Boulder during recent years. This nesting area is only a few miles from the site, and it therefore is not surprising that adult and immature birds have been observed hunting at RFETS. Peregrine falcons also migrate through the area. During 1994, peregrines were seen onsite in spring, early summer, and fall more commonly than in previous years.

The bald eagle, formally federally listed as endangered, has been reclassified for the lower 48 states as threatened (USFWS 1995). Bald eagles are increasingly

common in the region, occurring primarily as migrants or winter residents. To date, use of the site by bald eagles has been limited to overflights and occasional perching by birds probably associated with the reservoirs east of the site. A pair of eagles reportedly attempted unsuccessfully to nest at Standley Lake in 1992, 1993, and 1994.

Category 2 species are those species that may be appropriate for listing as threatened or endangered, pending a review of their status (USFWS 1994b). The Preble's meadow jumping mouse (PMJM) is the only Category 2 species that spends significant amounts of time at RFETS. PMJM have been captured in all three watersheds, including Smart Ditch, during intensive live-trapping programs in 1992, 1993, and 1994 (EG&G 1992, 1993b; DOE 1995c). Figure N2-7 shows the capture locations of PMJM and the distribution of apparently suitable habitat onsite. Animals were captured in riparian areas with well-developed shrub canopies and a relatively lush understory of grasses and forbs. This is typical of habitats occupied by the subspecies throughout its range.

N2.2 Contaminant Distribution

This section describes the general distribution of contaminants in the Walnut Creek and Woman Creek watersheds. The following subsections summarize information provided in TM2 (DOE 1995a).

Remedial investigations are currently being performed at 16 OUs designated at RFETS. Each OU contains several primary contaminant source areas, referred to as IHSSs. IHSSs were designated based on historical information, areas of surface disturbance indicated in aerial photographs, and preliminary site data. However, sources of contamination may not be confined to IHSS boundaries; contaminant sources may be associated with several IHSSs or OUs, and a given IHSS or OU may contribute to contaminant transport in both Walnut Creek and Woman Creek watersheds (Figure N1-3). The Walnut Creek watershed includes IHSSs from OUs 2, 4, 6, 7, 10, and 11, and the Woman Creek watershed includes IHSSs from OUs 1, 2, 5, and 11 (Figures N2-3 and N2-4).

OUs and PCOCs are briefly described below. A more detailed explanation of PCOCs and source areas is presented in Sections N3.2.2 and N3.2.3 of this document. PCOCs are listed by media for each OU in Table N2-1.

OU1 IHSSs include areas where contaminants were released into soils during disposal, storage, and dumping activities. Leaks and outfalls have also contaminated soils. The SID was built to prevent contaminants in OU1 from entering Woman Creek to the south. Radionuclides, volatile organic compounds

(VOCs), oils, and chromium are contaminants potentially migrating to Woman Creek from OU1.

OU2 IHSSs include burn sites, burial trenches, drum storage areas, a metals disposal site, and spray evaporation fields. Contaminants potentially migrating from surface and subsurface soil into both Walnut Creek and Woman Creek include radionuclides, VOCs, and oils.

The only IHSS in OU4 is the complex of solar evaporation ponds within the PA. These ponds were built to evaporate low-level radioactive wastes and neutralize acidic wastes. Plutonium, americium, uranium, and nitrate are the contaminants potentially migrating into surface and subsurface soil and groundwater northeast into Walnut Creek.

OU5 IHSSs include the ash pits, decontamination pad, incinerator, C-ponds, and old landfill. It also contains portions of the SID, which was built to prevent industrial area runoff from reaching Woman Creek. Uranium and plutonium are the principal potential contaminants associated with these sites.

OU6 IHSSs include the A- and B-ponds, trenches, soil dump area, sludge dispersal area, and spray fields. The A- and B-ponds held process and laundry wastewater. Plutonium, uranium, and nitrate are the principal potential contaminants associated with these sites.

OU7 IHSSs include the present landfill, spray evaporation fields, and an inactive hazardous waste storage area. Nitrate, tritium, and VOCs are potential contaminants associated with activities at these sites.

Relevant IHSSs in OU10 are the property utilization and disposal (PU&D) storage yard and container storage facilities. These sites have held drums of solvent and waste oils, spent batteries, and vehicles. VOCs and oils are potential contaminants associated with activities at these sites. PCOCs have not yet been identified for OU10.

The west spray field, the only IHSS in OU11, was used to enhance the evaporation of excess liquids from the solar evaporation ponds. Nitrate is the only contaminant potentially migrating into surface and subsurface soil and groundwater from OU11.

N2.3 Affected Environment

This section describes areas in the Walnut Creek and Woman Creek watersheds that could be affected by contaminants. Primary sources of contamination and general categories of receptors potentially affected are described. In addition,

because wind and water can transport contaminants from one source area to another, potentially affected downgradient areas are also noted.

N2.3.1 Walnut Creek Watershed

As noted in Section N2.1.4, the Walnut Creek watershed includes three basin segments: (1) undissected uplands west of the industrial complex, (2) relatively deep valleys separated by narrow ridges in the central portion, and (3) a broad area of low relief beyond the limits of the high terrace. The Walnut Creek watershed is more significantly altered than that of Woman Creek, containing several water diversion systems and 11 ponds on its three branches. This basin has also been highly modified by the extensive use of fill for construction of the industrial complex, as well as by the Present Landfill (OU7). Thus, the Walnut Creek watershed contains most of the production, storage, disposal, and spill sites at RFETS (DOE 1995a).

Most of the IHSSs in the Walnut Creek watershed are located in upland areas, including the Present Landfill (OU7), 903 Pad (OU2), East Trenches (OU2), Solar Ponds (OU4), West Spray Field (OU11), and Other Outside Closures (OU10). As noted in Section N2.2, these sites were used primarily for storage and disposal of wastes. Since the removal of the original contaminant sources, soils within these IHSSs are the primary residual contaminant source in the watershed. Species associated with the upland communities of the site may be exposed to PCOCs in soil, surface water, or groundwater.

The A-ponds and B-ponds are downgradient of the other IHSSs in Walnut Creek and thus may contain contaminants transported from primary source areas. Contaminants that have accumulated in water and sediments could affect the aquatic and wetland communities associated with these ponds. The potential for bioaccumulation and biomagnification of site contaminants is greatest for aquatic systems and upper level aquatic feeders.

N2.3.2 Woman Creek Watershed

Unlike the Walnut Creek watershed, the main channel of the Woman Creek watershed almost completely traverses the site from west to east. Most of the IHSSs in the Woman Creek watershed are located on the south-facing slopes of this drainage, including the Ash Pits (OU5), Old Landfill (OU5), 881 Hillside (OU1), 903 Pad (OU2), and East Trenches (OU2). Woman Creek IHSSs were used primarily for storage and disposal of hazardous materials. In some of the IHSSs, most notably the 903 Pad, hazardous wastes leaked from drums into surrounding soils; although drums have been removed, contaminated soils and groundwater

remain. Exposure to ecological receptors at these IHSSs is most likely to occur through contact with contaminated soils and surface water.

Vegetation at most of the IHSSs in the Woman Creek watershed consists of reclaimed grasslands, reflecting a history of physical disturbance. Although these reclaimed habitats do not support the same type or amount of use by wildlife as native grasslands, they nonetheless are important for some small rodents. Consequently, the reclaimed grasslands are used to some extent by predators such as coyotes and raptors. In addition, some of the Woman Creek watershed contains stretches of relatively well-developed riparian woodland.

Pond C-1 and Pond C-2 are downgradient of the other IHSSs in the watershed; thus, they may contain contaminants originating from other sites. Like the A- and B-ponds in Walnut Creek, the C-ponds are of particular concern because of the possibility for bioaccumulation and biomagnification of contaminants in aquatic systems. In addition, the wetland vegetation associated with the ponds increases the variety of potentially affected species and the potential intensity of their exposure. Pond C-1 is probably the most "natural" pond on either Walnut Creek or Woman Creek in terms of associated vegetation and persistent water levels. During surveys, the pond was found to contain a rich community of large fish, including largemouth bass. Pond C-2, while far from natural in appearance, supports a large population of fathead minnows due to the absence of predatory fish. The abundance of fish in these ponds results in heavy use by piscivorous birds, particularly herons.

N2.4 Sitewide Conceptual Model

This section presents a sitewide conceptual model (SCM) that describes the contaminant sources, release mechanisms, transport pathways, exposure routes, and key receptors present at RFETS. The model presented in this document has been developed according to concepts presented in detail in (DOE 1995a) and provides the basis for identifying key receptor species for which exposures will be estimated. As noted in Section N1, the ERAs for the Walnut Creek and Woman Creek watersheds focus on the potential effects of chemical stressors released during operation of the industrial facilities at RFETS.

N2.4.1 Sitewide Exposure Pathway Model

The contaminant transport and exposure mechanisms important in evaluating exposure of ecological receptors to contaminants at RFETS are presented in the exposure pathways models (EPMs) for grassland, riparian, and aquatic communities (Figures N2-8 and N2-9). The EPM identifies complete exposure pathways and describes the mechanisms by which contaminants are released.

transported, and taken up by receptors. The EPM is also used to identify measurement endpoints for estimating exposures (EPA 1989a, 1989b). In addition, the EPM provides a means of identifying exposure pathways that are potentially complete and that should be evaluated in the exposure analysis (EPA 1992a, 1994). The characterization of exposure pathways includes identification of the primary source of a contaminant, the primary mechanisms by which it is released and transported from the source, the point of potential contact with an ecological receptor (exposure point), and the mechanism by which the contaminant is taken up by an ecological receptor (exposure route) (EPA 1989a, 1989b). The components of the exposure pathway can be further defined as involving primary or secondary sources and release mechanisms. Potential sources of contamination and release mechanisms at RFETS are described in detail in TM2 (DOE 1995a) and summarized in the following subsections.

The types, sources, and distribution of contaminants used in the ERAs for Walnut Creek and Woman Creek were developed based on data from abiotic sampling associated with RCRA/CERCLA remedial actions at RFETS. In some cases where potentially ecotoxic concentrations were known to occur, additional data on contaminant distribution, contaminant bioavailability, or ecological effects were collected to reduce uncertainty in exposure estimates.

N2.4.2 Abiotic Exposure Points

Abiotic exposure points are locations where biota may contact contaminants in abiotic media. Based on data from RCRA/CERCLA field investigations, the following environmental media have been identified as potential abiotic exposure points:

Soils

- Surface soils (approximately 0 to 15 cm deep) in IHSSs or other source areas
- Subsurface soils (deeper than about 15 cm) in IHSSs or other source areas
- Surface soils downgradient of IHSSs or other source areas
- Subsurface soils downgradient of IHSSs or other source areas

Sediments

- Wet pond and stream sediments (approximately 0 to 15 cm deep) in IHSSs or other source areas
- Wet pond and stream sediments (approximately 0 to 15 cm deep) downgradient of IHSSs or other source areas
- Dry sediments along pond margins and ephemeral stream channels

Surface Water

- Surface water downgradient of soil IHSSs, including seeps and springs downgradient from burial trenches
- Walnut Creek, including A-ponds and B-ponds
- Woman Creek, including Pond C-1
- South Interceptor Ditch, including Pond C-2

Groundwater

- Shallow groundwater (< 6 feet below surface) in IHSSs or other source areas
- Shallow groundwater (< 6 feet below surface) downgradient from IHSSs or other source areas with known groundwater contamination

N2.4.3 Exposure Routes

Wildlife and aquatic organisms can be exposed to contaminants directly through contact with contaminated media (air, soil, sediment, water) or indirectly through consumption of forage that has been directly or indirectly exposed to contaminants. Exposure to vegetation may occur as a result of uptake of contaminants from soil, sediments, or water. Uptake can occur through the roots or, in some cases, lung tissue. The mechanisms by which a contaminant may be taken up are the exposure routes. The main exposure routes for wildlife at RFETS are ingestion of contaminants in food, soil, and water; absorption across external tissues; and inhalation (especially by burrowing animals).

N2.4.4 Food Web Interactions and Ecological Receptors

Food web interactions are an important consideration when designating ecological receptors because of the potential for bioaccumulation (DOE 1991, Fordham and Reagan 1991). Bioaccumulation can result in toxic exposures even when ambient concentrations are relatively non-toxic. Bioaccumulation occurs by absorption and accumulation of a chemical directly from abiotic media or through accumulation of contaminants ingested with food or water (Suter 1993). For most contaminants, the highest bioaccumulation potentials occur in an aquatic-based food web where contaminants from sediments or water bioconcentrate (Fordham and Reagan 1991). Bioconcentration is the process of absorption and accumulation of chemicals from water by aquatic organisms (Suter 1993).

Biomagnification is the successive accumulation of a pollutant in tissues with increasing trophic level. It is a significant mechanism of bioaccumulation for persistent organic chemicals such as chlorinated pesticides and some organo-metals

such as methyl-mercury. Ingestion is usually the most important intake mechanism leading to biomagnification.

In TM2 (DOE 1995a), food webs were used to identify the predominant pathways by which upper level consumers not normally exposed to contaminated media may be exposed to contamination through their food sources. Aquatic and terrestrial-based food web models were incorporated into grassland and riparian community EPMs (Figures N2-8 and N2-9), which were used to identify receptor guilds and representative receptor species outlined in TM2 (DOE 1995a).

N2.4.5 Other Factors Affecting Exposure Frequency and Duration

The magnitude of exposure to environmental contaminants is not only dependent on concentration but also on the frequency and duration of contact. For the most part, concentrations of contaminants in soil, sediment, and groundwater are relatively static, and resulting exposures are therefore relatively constant for resident species. Concentrations in surface water may change seasonally or in response to precipitation events, snowmelt events, or other factors affecting contaminant transport. The dominant factor controlling the exposure of ecological receptors is the behavior of individuals. Daily, weekly, and seasonal use patterns determine the amount of time an animal is in contact with contaminated media. These factors, considered on a case-by-case basis when estimating exposures to receptors, are described in Sections N3 and N4.

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CHAPTER N2

TABLES

Table N2-1
Summary of PCOCs by Medium
for Woman Creek and Walnut Creek Watersheds

Potential Contaminants of Concern	Woman Creek Watershed			Walnut Creek Watershed		
	OU1	OU5 ²	OU2 ³	OU4 ⁴	OU6	OU7
Metals	gw	ss,bh,sw,sd,gw	ss,bh,gw	bh,ss	ss,bh,sw,sd,gw	ss,bh,sw,sd,gw
Pesticides/PCBs	ss, sd	ss, bh	ss, bh, gw	ss	ss, sd	
Radionuclides	ss, bh, sw, sd, gw	ss, bh, sw, sd, gw	ss, bh, gw	bh, ss	ss, bh, sw, sd, gw	ss, bh, sw, sd, gw
Semivolatile Organic Compounds	ss, bh, sd	ss, bh, sw, sd, gw	ss, bh, gw	bh, ss	bh, sw, sd, gw	bh, sw, sd
PAHs	ss, bh, sd	ss	ss, bh, gw	ss	bh, sd	sd
Volatile Organic Compounds	ss, bh, sw, sd, gw	bh, sw, sd, gw	bh, gw	bh	bh, sw, sd, gw	bh, sw, sd, gw
Water Quality Parameters			bh, gw	bh, ss		ss, bh
						bh

¹OU1 PCOCs were identified using different statistical tests than the other OUs.

²PCOCs in surface water in OU5 and OU6 were further designated by type of surface water (streams, ponds, and seeps).

³OU2 is in both Woman Creek and Walnut Creek drainage basins.

⁴OU4-PCOCs have been identified only for surface soil and subsurface soil.

OU10-PCOCs have not yet been identified.

bh - borehole (subsurface soil)

gw - groundwater

sd - sediment

ss - surface soil

sw - surface water

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CHAPTER N2

FIGURES

N3. Preliminary Exposure and Risk Calculation

As noted in Section N1, the principal objective of this ERA is to evaluate risk due to chemical stressors (EPA 1994).

An initial step in conducting the watershed ERAs was to evaluate contaminant distribution data to determine which chemicals were present at potentially ecotoxic concentrations. This evaluation required screening-level exposure and risk estimations using data collected during RFI/RI activities and sitewide environmental monitoring programs. The screen corresponds to the preliminary exposure and risk calculation step of the EPA procedure for conducting ERAs at Superfund sites (EPA 1994).

The screening-level exposure and risk estimations are particularly important for ERAs at RFETS because the investigations are generally "source-driven" (Suter 1993). Potential sources have been identified in previous investigations, but there is little evidence of overt ecological stress. Exposures and more subtle toxic effects are largely uncharacterized. In addition, RFI/RI activities at the OUs resulted in an extremely large amount of data and identification of more than 150 PCOCs. Screening these data was necessary to focus more intensive risk evaluations on contaminants present at potentially ecotoxic concentrations and minimize evaluation of those that present negligible risk (Suter 1993).

A detailed description of the approach used for the preliminary exposure risk calculation is presented in Section N3.1, and the methodology is presented in Section N3.2. The results of the preliminary exposure and risk calculation are presented in Section N3.3.

N3.1 Tiered Approach

Preliminary exposure and risk calculations were performed according to procedures described in TM3 (DOE 1995b). The screening methodology was based on a phased approach, with analyses conducted in three tiers (Figure N3-1). This approach was designed to simultaneously screen data on more than 150 PCOCs for toxicity to several ecological receptor types in multiple contaminant source areas. The approach is based on conservative assumptions that minimize the chance of excluding chemicals that may represent ecological risk. Analyses conducted in Tier 1 are intended to identify site-specific contaminants based on distribution of chemicals in abiotic media. Tier 2 and Tier 3 include analyses of data from abiotic media and biological tissue to provide a preliminary evaluation of the potential

ecotoxicity of contaminants at the site. The result of the Tier 3 screening process is a list of ECOCs for which risk is characterized in Sections N4 and N5.

The purpose of Tier 1 was to identify the site-specific contaminants (PCOCs) that are the focus of the risk assessments for each OU. Tier 1 screening combines statistical comparisons to site background conditions, data on frequency of detection, and professional judgment. The process for identifying PCOCs was developed by DOE for RFETS in cooperation with EPA and CDPHE. The result is a list of PCOCs for each environmental medium that is then used to determine COCs for the HHRA and ERA, the two components of the RFI/RI Baseline Risk Assessment. The PCOCs and the process used to identify them are detailed in COC TMs prepared for OU-specific HHRA's. EPA and CDPHE must review and approve each of the COC TMs. The ERA exposure and risk screening was conducted using a sitewide list of PCOCs generated by combining the OU-specific lists. PCOCs are listed in Section N3.2.1.

Tier 2 and Tier 3 ecotoxicity screens were conducted for a set of key receptor species that were selected to represent taxonomic and functional groups of ecological receptors. Representative species of birds, small mammals, large mammals, and fish were selected based on their abundance at RFETS, special legal status, and position in local food webs. Information on life history, body size, diet, and other parameters needed to estimate exposure was assembled and documented for review and approval by regulatory agency personnel (DOE 1995b).

The most conservative estimates of exposure were used for the Tier 2 screening evaluation. This screening step assumed that each receptor lives year-round in areas containing the maximum contaminant concentration and that 100 percent of each contaminant is absorbed from environmental media. These assumptions overestimated exposure under most conditions, minimizing the chance of eliminating a potentially ecotoxic contaminant from further risk evaluation. During the Tier 2 evaluation, maximum PCOC concentrations were compared to estimated concentrations in drinking water (C_w) and food (C_f). Few PCOCs were removed as a result of the Tier 2 analysis. Therefore, all PCOCs were carried over to the Tier 3 phase of the evaluation.

Although Tier 3 is considered a screening step, it includes a more accurate method for estimating exposure than Tier 2. The Tier 3 screen incorporates the distribution of chemicals in the environment and the spatial and temporal aspects of receptor behavior. Factors such as diet, body size, home-range size, and seasonal migration affect the frequency, duration, and intensity of contact with contaminated media. Adjustment of exposure parameters to account for these factors is important to obtain more objective exposure and risk estimates. The more intensive level of

screening included in Tier 3 is particularly appropriate in source-driven (Suter 1993) ERAs in which source areas may contain several potential contaminants, but the effects of contaminant exposure are not apparent.

The primary objective of the tiered ecotoxicity screen is to evaluate exposures to determine whether the chemical concentrations represent an ecotoxicological threat. The risk was evaluated by comparing site exposures to toxicity reference values (TRVs) that are benchmark exposures over which adverse ecological effects could occur. TRVs were derived to represent the No Observed Adverse Effects Level (NOAEL) for sublethal systemic and reproductive effects. Derivation of TRVs for the Tier 3 screen is described in Section N3.2.6.

As described in TM3 (DOE 1995b), the Tier 3 screen was designed so that (1) the contributions to overall ecological risk from each exposure-point medium and each contaminant source area could be quantified and (2) the primary factors contributing to risk within specific areas could be identified. To accomplish this, the IHSSs were grouped into ERA source areas according to OU, contaminant sources, sampling locations, and habitat (Figures N3-2 and N3-3).

Source areas ranged in size from 1 to more than 45 hectares and included areas with and without surface water such as streams and ponds (Section N3.2.2). The relative contribution of each source area to total risk in the watershed or site was identified by ranking source areas according to risk. Information on the major sources of risk can be used in prioritizing remedial action decisions to gain the most cost-effective reduction of risk within the assessment area.

As noted above, the ECOC screen was conducted according to procedures described in TM3 (DOE 1995b). The following subsections describe the specific approach and methods used in identifying source areas, aggregating data, and estimating exposures for key receptors.

N3.2 Methods

Details of screening methods, exposure estimations, and development of ecotoxicological benchmarks are presented in the following sections (Figure N3-4). Radiological exposures were estimated separately due to differences in benchmark values, receptors, and ecological effects and are discussed separately in Section N3.2.5.

N3.2.1 PCOCs

The sitewide ERA PCOCs were identified during Tier 1 evaluation by consolidating the PCOC lists generated for each OU included in this analysis.

Because PCOC lists are unique for each media type, only PCOCs with complete exposure pathways were considered in developing the PCOC list for the sitewide ERA. Some analytes included in RFETS target analyte lists (TALs) are not appropriate or useful for examining toxicological risk to ecological receptors. Those inappropriate analytes have been omitted from further consideration (Table N3-1). The sitewide ERA PCOC lists are presented for each medium in Tables N3-2, N3-3, N3-4, and N3-5.

N3.2.2 Identification of ERA Source Areas

Because of the large area of RFETS and the large number of plant and animal species occurring at the site, it was impractical to evaluate exposures during Tier 3 evaluation for all possible receptors from all possible locations. Therefore, exposures were estimated for the known contaminant source areas for a representative group of species (key receptors).

The purpose of the sitewide ERA is to provide information that is useful for both evaluating ecological risk on a watershed basis and making decisions regarding remedial actions associated with the individual OUs and IHSSs within them. Sitewide ERA source areas were identified by grouping together certain IHSSs across the site, based on their associated abiotic and biotic sampling locations (Table N3-6). This aggregation of IHSSs provided manageable units (source areas) containing the majority of sampling locations with which to measure the effects of direct contamination and its short-range transport to sensitive habitats and individual receptor sites (Figures N3-2, N3-3, and N3-4).

N3.2.3 Identification of Key Receptors

Key receptor species were selected from among candidate receptor species that represent feeding guilds at RFETS (DOE 1995b) for inclusion in the Tier 2 and Tier 3 screening evaluation. Two categories of key receptors were identified: limiting species and wide-ranging species. Limiting species have small home ranges and are most sensitive to contamination, and wide-ranging species have relatively large home ranges and are potentially subjected to a much larger array of contaminants. The criteria for use in the ERA are described below. As previously stipulated in TM2, key receptor species:

- are common or keystone species in the local ecosystem
- represent functional groups and feeding guilds
- have significant home ranges within RFETS
- have complete exposure pathways
- are susceptible to toxic effects of contaminants under consideration
- have known life-history parameters

For each receptor, exposure was estimated for all exposure routes having potentially complete exposure pathways. Complete exposure pathways were determined for each source area based on the EPMs (Figures N2-8 and N2-9). Key receptor species potentially present in each source area were determined based on habitat preference and vegetation types present (Table N3-7).

As shown in Figures N2-8 and N2-9, potential exposure routes for wildlife receptors include ingestion of contaminants in food, soil, sediments, and water; inhalation of volatile contaminants; and dermal absorption of contaminants in air, soil, sediments, and water. Exposures from dermal absorption of contaminants or inhalation of contaminated particulates were not estimated for wildlife receptors at RFETS because exposures were more conservatively estimated from ingestion pathways. Radionuclide intakes were evaluated based on accumulated body burdens and environmental screening levels (Higley and Kuperman 1995). The principal exposure route for aquatic organisms is absorption of contaminants in surface water and sediments through integuments (skin and gills). Vegetation may be exposed to contaminants through direct contact with contaminated soil and water or through root uptake of soil contaminants.

Exposure pathways analyzed (Table N3-8) were determined with the principal dietary components (Table N3-7) and data types available. Available biotic data include small mammals, terrestrial arthropods, benthic macroinvertebrates, and fish. A complete description of data available is presented in Table N3-9.

N3.2.3.1 Limiting Species

Because limiting species may live within the confines of a single source area, potential exposure to these receptors was assessed for each source area. The following primary receptors represent limiting species at RFETS.

Preble's Meadow Jumping Mouse

PMJM was chosen to represent small mammals in the EPM. The home range of this species is such that individuals captured within most source areas are likely to have spent most of their lives there (Figure N3-7). Because of their status as a federal Category 2 species, risk to PMJM was assessed at the individual level during the problem formulation and risk characterization phases of the risk assessment.

Exposure risk to PMJM was evaluated by estimating contaminant uptake through ingestion of contaminated vegetation and terrestrial arthropods, as well as incidental ingestion of soil and dry sediments. In addition, organic contaminants in soil may volatilize and accumulate in animal burrows. Therefore, the potential for

exposure to organic contaminants in burrow air was assessed for source areas with elevated organic concentrations in subsurface soil.

American Kestrel

The American kestrel represents raptorial receptors with a small home range in the EPM. Kestrels are common at RFETS and in surrounding grassland areas year-round. However, they are migratory, and the same individuals do not spend the whole year at RFETS. Because other raptor species found at RFETS have much larger home ranges, exposure estimates for the American kestrel home range are likely to overestimate exposure to other raptors.

Exposure risk to American kestrels was evaluated by estimating contaminant uptake through ingestion of contaminated terrestrial arthropods and small mammals, as well as incidental ingestion of soil while feeding on these prey.

Great Blue Heron

Great blue herons represent large wading piscivorous birds in the EPM. Great blue herons are common during the summer, uncommon during spring and fall migration, and not present during the winter.

Exposure risk to great blue herons was evaluated by estimating contaminant uptake through ingestion of contaminated fish, surface water, and sediments. Because they may feed on carnivorous fish species, herons represent tertiary consumers and therefore are appropriate for evaluating the bioaccumulation potential of organic contaminants in aquatic systems.

Mallard

Mallards represent the various "dabbling" ducks that occur at RFETS. Mallards feed on plants, invertebrates, and seeds in pond sediments as well as terrestrial or aquatic plants. Because mallards are in frequent and prolonged contact with surface water and sediments, they are appropriate receptors for evaluating the potential for dermal exposure potential of organic contaminants in aquatic systems.

Exposure risk to mallards was evaluated by estimating contaminant uptake through ingestion of benthic macroinvertebrates, vegetation, surface water, sediments, and surface soil.

N3.2.3.2 Wide-Ranging Species

Potential exposure to wide-ranging species was assessed on a sitewide basis because the home range sizes of these animals often exceed the total area of the

RFETS buffer zone (2,634 hectares [ha]). The following species represent wide-ranging species at RFETS.

Coyote

Coyotes are the most common mammalian predator at RFETS (DOE 1992). Although the primary food of this predator is small mammals, vegetation is also consumed. The coyote represents widespread and wide-ranging omnivorous species. Home range is approximately 1,130 ha (Gese *et al.* 1988), and essentially all habitats at RFETS are used (Towry 1987).

Because of their varied diets, coyotes are potentially exposed to a wide variety of contaminants. Additionally, because coyotes are secondary or tertiary consumers, they may exhibit bioaccumulation effects. Exposure risk to coyotes was evaluated by estimating contaminant uptake through ingestion of small mammals, vegetation, surface soil, and surface water.

Mule Deer

Mule deer are year-round residents and are the most abundant large herbivore at the site (DOE 1992). They represent widespread and wide-ranging herbivores in the EPM. Like the coyote, mule deer have a large home range (285 ha) and use a variety of habitats. Mule deer obtain essential salts by eating soil and possibly dry sediments; thus, their intake of soil may be substantial.

Risk to mule deer was evaluated by estimating contaminant uptake through ingestion of vegetation, sediments, surface soil, and surface water. For exposure assessment purposes, it is assumed that the amount of time a deer spends in an area is directly proportional to the fraction of its home range that the area of concern represents.

Red-tailed Hawk

The red-tailed hawk is one of the most common raptors in the United States and is a top predator at RFETS (DOE 1992). Red-tailed hawks represent wide-ranging raptorial species in the EPM. Home ranges are approximately 650 ha (Smith and Murphy 1973, Peterson 1979). Red-tailed hawks are present year-round at RFETS. However, they are migratory and are present in much greater numbers in the summer than winter (DOE 1993c). Red-tailed hawks are tertiary consumers and thus may be susceptible to effects of bioaccumulation.

Exposure risk to red-tailed hawks was evaluated by estimating contaminant uptake through small mammals and incidental ingestion of soil associated with prey items.

N3.2.3.3 Other Receptor Types

Aquatic Organisms

All source areas with the potential for aquatic life were screened to determine risk of exposure to aquatic contaminants. State surface water quality standards are based on ambient water quality criteria (AWQC), which evaluate various toxicity tests. Some of these toxicity tests have included research on amphibians while others have not.

Vegetation

No specific vegetation receptors were chosen because little information is available on toxicity to native species of vegetation. Instead, entire communities were assessed for effects of toxic exposure (Figures N3-5 and N3-6).

N3.2.4 Nonradionuclide Exposure Estimation

Nonradiological contaminant exposure to ecological receptors was estimated for individuals on a source-area, watershed, and sitewide basis. Methods used to estimate exposure to ecological receptors are described below.

N3.2.4.1 Exposure-point Concentrations

Data used in exposure estimates were collected during RFI/RI activities. Exposure-point concentrations for PCOCs in abiotic and biotic media were estimated from the 95 percent upper confidence limit of the mean (UCL₉₅). However, where the UCL₉₅ was greater than the mean, the maximum detected concentration was used as the exposure-point concentration. Tissue data for vegetation, terrestrial arthropods, benthic macroinvertebrates, fish, and small mammals were used to estimate exposure from ingestion of forage or prey items.

In some cases where biotic data were not available, tissue contaminant concentrations were calculated from abiotic data. Where contaminant concentrations were not available for benthic macroinvertebrate and fish tissue, exposure-point concentrations were calculated from surface water data using the following equation (referred to as estimated values):

$$\text{Exposure-point concentration} = BCF \times \text{Surface Water Concentration (dissolved)}$$

where:

BCF = bioconcentration factor

BCFs are the ratio of concentrations in aquatic organisms to concentrations in water. Where no experimental data were available for BCFs, they were calculated from equilibrium partitioning data, according to the following relationship (Lyman *et al.* 1982).

$$\log BCF = 0.76 \log K_{ow} - 0.23$$

where:

Log K_{ow} = the octanol-water partition coefficient

BCFs and log K_{ow} values used for this analysis are shown in Attachment 1, Tables 1 and 2.

Contaminant concentrations in vegetation were not available for all source areas. Where necessary, concentrations were calculated using the following equation (Travis and Arms 1988):

$$U = B \times C_s$$

where:

U = vegetation tissue concentration from soil uptake

B = transfer coefficient calculated from $\log B = 1.588 - 0.578 \log K_{ow}$

C_s = contaminant concentration in soil

Transfer coefficients used to calculate contaminant concentrations in vegetation are listed in Attachment 1, Table 2. Biota data available or estimated from abiotic media are shown in Table N3-9.

N3.2.4.2 Wildlife Exposure Estimations

Ingestion

Exposure due to ingestion of contaminated food, water, soil, and sediment was estimated from exposure-point concentrations and species-specific ingestion rates. As explained in TM2 (DOE 1995a), ingestion rates and other species-specific exposure parameters were obtained from the scientific literature or derived from

information provided in the Wildlife Exposure Handbook (EPA 1993a). Bioavailability of contaminants was assumed to be 100 percent for all chemicals in all media.

For a given species, intakes were calculated using the following equation (EPA 1994, ORNL 1994, DOE 1995b):

$$\begin{aligned} \text{Total Contaminant Intake} = & (C_{\text{soil/sediment}} \times IR_{\text{soil/sediment}}) + (C_{\text{water}} \times IR_{\text{water}} \times \text{SUF}_{\text{water}}) \\ & + (C_{\text{prey}} \times IR_{\text{prey}} \times \text{SUF}_{\text{prey}}) + (C_{\text{forage}} \times IR_{\text{forage}} \times \text{SUF}_{\text{forage}}) \end{aligned}$$

where:

C_{medium} = exposure-point concentration of PCOC in environmental medium (i.e., prey, forage, soil, or water)

IR_{medium} = ingestion rate for environmental medium

$\text{SUF}_{\text{medium}}$ = site use factor (SUF) for environmental medium

Parameters used to estimate exposure were adapted for each receptor species at each source area (Tables N3-10 through N3-16; Attachment 1, Table 3). Environmental media for which intakes were calculated were determined based on the behavioral characteristics of the receptor species under consideration. Total food ingestion rates were divided among general biota types (vegetation, terrestrial arthropods, benthic macroinvertebrates, fish, and small mammals), according to the proportion of the receptor diet they represent. Where biotic contaminant concentrations could not be estimated, the total food intake rate was partitioned among prey and forage categories for which data were available. For example, for PMJM, terrestrial arthropods represent approximately 30 percent of the total food intake (DOE 1995a). Because terrestrial arthropod data were not available for OU6 A-Ponds, vegetation was assumed to represent 100 percent of the total food intake for PMJM at this site.

Estimates of contaminant intake were also adjusted by an SUF representing the proportion of time spent in each source area relative to surrounding areas (e.g., home range). SUFs were determined primarily by the proportion of the receptor's home range that was represented by the source area under consideration. Where a receptor's home range was smaller than the source area, the SUF was 1.00. SUFs were also based on species-specific behavioral patterns and exposure routes. For example, because mule deer drink primarily from pond and stream edges, the mule deer SUF for surface water intake was based on pond perimeters and stream lengths within the source area as a proportion of the total length of pond and stream edge available within the home range. Seasonal use patterns could also influence SUFs; however, exposure estimates were based on the assumption that wildlife receptors

are present at the source areas year-round. In most cases, this assumption overestimates the risk to migratory species such as the mallard, great blue heron, and American kestrel. SUF calculations for species with home ranges greater than individual source areas are presented in Attachment 1, Tables 4 through 9.

Inhalation

Exposure due to inhalation was estimated for small mammals, represented by PMJM, for all source areas with buried waste. The concentration of volatile contaminants in a hypothetical animal burrow was estimated using subsurface soil exposure-point concentrations and the following equation adapted from Maughan (1993):

$$C = \frac{(V_p \times MW) \times 1,000 \text{ mg / g}}{(R \times T)}$$

where:

C = concentration of contaminant in burrow air

V_p = partial pressure of the contaminant (atm)

MW = molecular weight of the contaminant

R = ideal gas-constant (m³ atm/mole °K)

T = burrow temperature in °K; assumed to be 280.1°K

Vapor pressures were calculated using the concentration of the contaminant in soils and Henry's Law constant. The method assumes equilibrium between soil and air and a closed air space. Vapor pressures were calculated according to the following equation:

$$V_p = H \times C_{\text{soil}}$$

where:

H = Henry's Law constant

C_{soil} = concentration of the contaminant in soil

N3.2.4.3 Vegetation

Potential exposure of vegetation to contaminants was estimated from subsurface soil PCOC concentrations. Subsurface soil data were used because (1) subsurface soil had the largest suite of chemicals analyzed, (2) most plants have roots that

extend below the first two inches of surface soil, and (3) most toxicity data are based on concentration of contaminants in soil (Suter 1993).

N3.2.4.4 Aquatic Organisms

Exposure of aquatic organisms to contaminants was estimated for direct contact to sediments and surface water. Exposure of sediment-associated biota, such as benthic macroinvertebrates, was estimated from sediment PCOC concentrations from individual ponds and stream reaches with sediment sampling locations. In some OUs, PCOCs were assigned separately for ponds and streams. Sediment samples from the SID and the unnamed tributary to Walnut Creek were not used in exposure estimates because they were not considered relevant aquatic habitat.

Exposure of aquatic biota to surface water PCOCs was estimated from dissolved (filtered) concentrations. Dissolved concentrations are most appropriate for evaluation of toxicity to pelagic organisms because Colorado water quality standards are based on dissolved concentrations, and transdermal and gill intake are the principal exposure routes for these organisms.

N3.2.4.5 Assumptions

In an effort to treat source areas consistently while estimating exposures more realistically, several assumptions were made regarding receptor behavior and source area characteristics. These sources of uncertainty are listed in Table N3-17.

N3.2.5 Radionuclide Exposure Estimation

Estimation of radionuclide exposure was based on the maximum detected concentration in the surface soil, surface water, and sediments at RFETS. Exposures were estimated only for the species found to be most susceptible to contamination in the environmental media in question. The limiting species defined in Higley and Kuperman (1995) are small mammals for surface soil and aquatic life for surface water and sediment. No estimated exposure values were used.

N3.2.6 Risk Estimations

Potential ecotoxicity of contaminants was assessed during the Tier 3 evaluation by comparing site-specific exposures to ecotoxicological benchmarks. The comparison is expressed as a Hazard Quotient (HQ), which is the ratio of a site-specific exposure estimate to an ecotoxicological benchmark (EPA 1994, DOE 1995b):

$$HQ = \frac{\text{Estimated Exposure}}{\text{Benchmark Exposure}}$$

An HQ greater than 1 was interpreted as a level at which adverse ecological effects could potentially occur. An HQ less than 1 was evaluated based on potential ecotoxicity, bioaccumulation or biomagnification, and magnitude of the calculated quotient.

The risk to wide-ranging species for each PCOC was assessed as the mean source area HQ (HQ_{mean}):

$$HQ_{\text{mean}} = \frac{\sum HQ_{\text{source areas at RFETS}}}{\text{Number of Source Areas at RFETS}}$$

Cumulative risk resulting from exposure to multiple contaminants was evaluated using the hazard index (HI) approach (EPA 1994). The HI approach assumes that the effect of exposure to multiple chemicals is an additive function. The HI is calculated as the sum of HQs for individual chemicals (DOE 1995b). For example:

$$HI = HQ_{\text{aluminum}} + HQ_{\text{barium}} + HQ_{\text{etc.}}$$

An HI less than 1 indicates negligible, or *de minimis* risk (Suter 1993). An HI greater than 1 indicates potentially significant risk, even if no single HQ is greater than 1. Cumulative risk for each watershed is summarized as the watershed HI ($HI_{\text{watershed}}$), which is the sum of HIs from each source area within a watershed.

$$HI_{\text{watershed}} = \sum HI_{\text{source areas in watershed}}$$

Cumulative risk for the entire site is summarized as the total HI (HI_{total}), which is the sum of the HIs from each source area:

$$HI_{\text{total}} = \sum HI_{\text{source areas at RFETS}}$$

Risk of effects to individual organisms is the basis for exposure benchmarks and HQ and HI calculations. This level of risk estimation is adequate for threatened/endangered species or other sensitive species for which protection of individual organisms is desired. However, for species that are not protected or rare, protection of populations is more appropriate (Barnhouse 1993). Therefore, extrapolation of exposure estimates to population-level effects should be considered in risk management decisions. Qualitative discussions of population-level effects are included in the risk characterization section for each species (Sections N4 and N5).

N3.2.7 Toxicity Reference Values

The TRVs used in risk estimations were derived from several sources of information on ecotoxicity of PCOCs and native or background concentrations estimated for RFETS. Information on NOAELs or other ecotoxicological benchmarks was obtained primarily from a database developed for DOE at ORNL (Hull and Suter 1994, Opresko *et al.* 1994, Suter and Mabrey 1994, Will and Suter 1994). Other sources of information included:

- EPA-supported databases such as the Integrated Risk Information System (IRIS) and Aquatic Information Retrieval (AQUIRE)
- U.S. Fish and Wildlife Service (USFWS) contaminant hazard reviews
- Colorado water quality standards
- EPA AWQC
- Scientific literature

For naturally occurring metals, literature-based benchmarks were compared to exposure estimates for background concentrations in soil, sediment, and surface water at RFETS. The background exposure was used as the TRV when it exceeded the literature-based benchmark. It was assumed that most organic compounds do not occur naturally; therefore, NOAELs for organic compounds were not compared to background concentrations. Surface water TRVs for exposure to aquatic organisms also were not compared to background (Section N3.2.7.3). Development of TRVs for wildlife, vegetation, and aquatic organisms is described in the following subsections. Radionuclide benchmarks, which were developed separately, are described in Section N3.2.8.

N3.2.7.1 Terrestrial Wildlife

No state or federal standards currently exist for regulating exposure of wildlife to anthropogenic chemical contaminants. Risk evaluations and remediation decisions are predicated on criteria developed in site-specific ERAs. A process for developing ecotoxicological benchmarks and a database for some chemicals and receptor types is presented in Opresko *et al.* (1994). The benchmarks were derived to approximate NOAELs, which represent the greatest exposures at which no adverse effects are observed. NOAELs (and benchmarks) may be expressed as a dose (e.g., milligrams contaminant ingested per kilogram body weight [bw] per day [mg/kg_{bw}-day]) or as environmental effects criteria (EECs) (e.g., milligrams of contaminant per liter water [mg/L]).

ERAs are intended to assess risk to populations for species not listed as threatened or endangered. Therefore, ecotoxicological standards for birds and mammals derived from toxicological studies that measure reproductive effects were preferred because they represent effects to populations, not individuals. Studies conducted for species at critical life stages are most protective of populations. However, these studies are not available for all chemicals and species of interest at RFETS. Endpoints from databases such as EPA's IRIS generally are not based on reproductive studies and therefore reflect risk to individuals, not populations.

Methods

Because avian and mammalian physiologies differ significantly, NOAELs can vary by a factor of 1,000 or more for the same chemical. Therefore, NOAELs for birds and mammals were developed separately following the process outlined by ORNL (Opresko *et al.* 1994) (Attachment 2, Table 1). Extrapolations among similar species were performed using a scaling factor derived from an empirical relationship between body size, body surface area, and other physiological functions (EPA 1980, 1986a, 1986b, 1988, 1989c):

$$NOAEL_w = NOAEL_t (bw_t/bw_w)^{1/3}$$

where:

$NOAEL_w$ = wildlife NOAEL

$NOAEL_t$ = test species NOAEL

bw_t = test species body weight

bw_w = wildlife body weight

NOAELs for mammals and birds were extrapolated to RFETS site-specific receptor species. These receptor-specific NOAELs and the TRVs derived from the NOAELs are presented in Attachment 2, Tables 2 through 8.

Burrowing animals can also be affected through inhalation of soil gases in burrows. Ecological effects criteria were developed by using the ideal gas law to calculate maximum soil concentrations that would result in acceptable exposure to burrow occupants. The ecological effects criteria were calculated by estimating partial pressure corresponding to the TRV (Maughan 1993). The corresponding soil concentrations were then calculated using Henry's Law and assuming equilibrium between soil and air within a closed burrow. Equations used in exposure calculations are provided in Section N3.2.4.

Assumptions

Extrapolating toxicity information between species requires a variety of assumptions. Endpoints that affect reproductive success were preferred. When chemical-specific information was unavailable or inappropriate, a structurally similar chemical was used as a surrogate for the chemical in question. For example, extensive toxicity tests have not been conducted for polycyclic aromatic hydrocarbons (PAHs), toxicity equivalency factors (TEFs), as outlined in EPA (1992b, 1993b) and Nisbet and LaGoy (1992), were used to estimate NOAELs where PAH-specific information was unavailable. TEFs compare the relative toxicities of the various PAHs to benzo[a]pyrene and allow NOAELs to be extrapolated for all PAHs found at RFETS. Extrapolations among chemicals are noted in Attachment 2, Table 1.

Extrapolating NOAELs from laboratory animals to wildlife introduces uncertainty. Laboratory animals often are inbred and live in a controlled environment, whereas wild animals are genetically more variable and subject to a wide variety of environmental conditions. Consequently, laboratory and wild animals may differ in their tolerance or sensitivity to a chemical. In addition, bioavailability of chemicals may differ between experimental and natural conditions. Uncertainty factors were used to adjust a lowest observed adverse effect level (LOAEL) to a NOAEL and subchronic to chronic exposure (Attachment 2, Table 1). Short-duration exposures that occurred during reproduction were considered chronic for the following reasons: (1) the stressed condition of the adults, (2) rapid growth of the young, (3) the critical developmental stage of the young, and (4) the potential to impact the population.

Adjusting NOAELs from one species to another also introduces uncertainty. For example, larger animals often are more vulnerable to xenobiotics than are smaller animals because large animals have slower metabolic rates. However, where the toxicity of a compound is through bioactivation, this vulnerability may be reversed.

N3.2.7.2 Vegetation

Twenty-four soil-based vegetation TRVs were developed in addition to values presented in Will and Suter (1994). Although toxicity data exist for a variety of chemicals and plants, no methods have been developed for comparing or standardizing phytotoxic endpoints. The plant values presented in Attachment 2, Table 9 are based on the methodology presented in Will and Suter (1994).

Methods

Available plant toxicity information encompasses a variety of growth media. Information on plant growth in soil was used for this risk assessment. Data from plants grown in media such as vermiculite or sand were omitted because these media rarely represent natural growing conditions (Will and Suter 1994).

The Will and Suter (1994) methodology used a number of references in choosing a vegetation benchmark. A comparable number of references was not available due to a paucity of phytotoxicity data. Therefore, the level of confidence in the benchmarks is unknown. Available and relevant data for the benchmarks developed for this report are presented in Attachment 2, Table 9. Chemical benchmarks are presented in Attachment 2, Tables 10 and 11.

Assumptions

Availability of xenobiotics in soil is normally determined by the root uptake system. Metals may enter the root through a variety of mechanisms, including passive uptake within complexes and active substitution for nutrients. Metals may also sorb to the root exterior. Organic compounds can enter a plant through the root system, although molecules larger than 500 daltons are too large. Smaller organic compounds may be excluded because of polarity. Less water-soluble compounds have limited access to the plant, while more water-soluble compounds are taken up through the epidermis and translocated through the plant. Symplastic uptake and translocation is possible for very lipophilic compounds.

Bioavailability varies widely among chemicals and may vary for a specific chemical depending on environmental conditions. The bioavailability of metals is influenced primarily by soil pH, cation exchange capacity (CEC), and moisture content. Metals are often complexed with other soil constituents or sorbed to the mineral fraction of a soil. Non-ionic organics tend to sorb to the organic fraction of soil. The behavior of ionic organic compounds in soil is determined by a variety of factors, including pH and the characteristics of the organic compound and soil. The influence of plant roots in the rhizosphere also alters bioavailability.

Different analytical techniques used to estimate chemical concentrations in soil can produce markedly different results that can over- or under-estimate bioavailability. Acid extractions for metals and solvent extractions for organics are used to determine the total concentration of a contaminant in a medium. These extractions often overestimate the bioavailable concentration of the compound to which the plant is exposed. Therefore, phytotoxicity data are inappropriate or a poor measure

of risk for cases in which benchmarks exceed background, benchmarks exceed site data, and the plant community is thriving and diverse.

N3.2.7.3 Aquatic Life: Surface Water Standards (TRVs)

Risks to aquatic life were assessed for exposure to pond and stream water. Ecotoxicological benchmarks for these types of surface water (Attachment 2, Table 12) were based on Colorado surface water standards for protection of aquatic life (5 CCR 1002-8), EPA AWQC, or risk-based values derived from other sources such as the environmental restoration program at ORNL (Suter and Mabrey 1994). Because the surface water standards are promulgated standards, no background comparison was performed.

Statewide standards have been promulgated for some metals and indicator parameters but not for most organic compounds or radionuclides (5 CCR 1002-8, September 1993). The Colorado Water Quality Control Commission (CWQCC) has classified segments of Walnut Creek and Woman Creek at RFETS as capable of supporting "Class 2 Aquatic Life." Class 2 streams are not capable of sustaining a wide variety of aquatic fauna due to a lack of physical habitat, insufficient flow, or uncorrectable water-quality conditions (5 CCR 1002-8, April 1993). Aquatic standards for Class 2 stream segments are set on a site-specific basis. The CWQCC published site-specific standards for some organics and radionuclides for segments 4 and 5 of the Big Dry Creek basin, which includes parts of RFETS (5 CCR 1002-8, April 1993).

Colorado standards are based on EPA AWQC. These criteria use available toxicological data from multiple studies and species to derive water-borne chemical concentrations that are not expected to result in toxicity to 95 percent of the species for which data are available. Criteria and water-quality standards are available for evaluating acute and chronic exposures. Chronic criteria and standards were used where available. Because they are based on the AWQC, the Colorado standards are considered risk-based criteria.

Aquatic benchmarks presented in ORNL (1994) may be used when neither state water quality standards nor AWQC are available. The endpoints used in ORNL (1994) are based on effects at population and community levels and differ from those used in the AWQC. The resulting ORNL benchmarks tend to be less stringent than Colorado standards. Benchmarks in ORNL (1994) may also be used to supplement the Colorado standards in interpreting risks to aquatic biota.

N3.2.7.4 Aquatic Life: Sediment TRVs

Sediment quality benchmarks (SQBs) were derived from EPA guidance on estimating sediment quality criteria (EPA 1992c) and from risk-based sediment benchmarks developed from other freshwater sites in the United States and Canada (Hull and Suter 1994). Benchmarks for most non-ionic organic compounds used the equilibrium partitioning approach recommended by EPA (1992c). This approach is based on the assumption that sediment toxicity is primarily dependent upon contaminant concentration in the interstitial water. Information on the aqueous solubility of the contaminant and the total organic carbon content of the sediment is used to estimate a concentration in bulk sediment that would result in an interstitial water concentration equal to the water-quality benchmark. Benchmarks for metals in sediments were taken primarily from risk-based values developed for freshwater habitats at other sites (Hull and Suter 1994).

EPA has developed interim sediment quality criteria (ISQC) for a limited set of organic chemicals. When these criteria were available, they were used as the basis for sediment benchmarks, as shown below:

$$SQB = f_{oc} \times ISQC$$

where:

f_{oc} = fraction of organic carbon

The Hull and Suter (1994) approach, used for non-ionic organics without ISQC, is shown below.

$$SQB = f_{oc} \times K_{ow} \times WQS$$

where:

K_{ow} = octanol-water partition coefficient

WQS = water quality standard

Both methods of developing organic sediment benchmarks rely on the f_{oc} in the sediment. Therefore, sediment benchmarks for organics were developed on a pond-by-pond basis. Sediment TRVs are presented in Attachment 2, Table 13.

N3.2.7.5 Radionuclide TRVs

Benchmarks for evaluation of radionuclide exposure were developed by a consortium of scientists from RFETS, Los Alamos National Laboratory, Argonne National Laboratory, and Oregon State University (Higley and Kuperman 1995).

These radiological benchmarks are based on a limiting species concept with a dose limit of 100 mrad/day for terrestrial and aquatic species. Data show that population-level or reproductive effects to ecological receptors have not been observed at this dose limit (Higley and Kuperman 1995). Limiting tissue concentrations (or activities) were back calculated from the dose limit. Radionuclide-specific benchmarks accounted for the differing biological effectiveness of the various decay types, as well as total radionuclide exposure, bioaccumulation, and bioconcentration. Benchmarks for soil, sediment, and surface water were developed, including alternative pathways of exposure to each receptor. No background comparison was included in the radionuclide benchmarks because they were developed specifically for RFETS. Radionuclide benchmarks are provided in Attachment 2, Table 14.

Small mammals were chosen as the limiting terrestrial species for the surface soil exposure route. Soil exposures included concentration ratios and the ratio of radionuclide concentration in abiotic media to the chemical concentration in tissue. Vegetation benchmarks for radionuclides were not available. However, RFETS-specific small mammal benchmarks for radionuclides are presented in lieu of vegetation benchmarks because they are considered to be protective of all ecological receptors (Higley and Kuperman 1995).

Surface water benchmarks were based on potential effects to aquatic species because benchmarks derived for aquatic species are more restrictive than those for terrestrial species. The surface water methodology used a concentration ratio (Section N3.2.6). The CWQCC published site-specific standards for some radionuclides in segments 4 and 5 of the Big Dry Creek basin, which includes parts of RFETS (5 CCR 1002-8, April 1993).

Sediment benchmarks included both water column and sediment dwellers. Sediment benchmarks were developed with a distribution coefficient that was the lesser of the bioconcentration factor and the concentration ratio.

N3.2.8 Data Management

Initially, PCOCs were to be screened using the original contractor data sets. However, it was not possible to combine data sets due to substantial differences in data management procedures, final formats, and the possibility of duplicated data between data sets. Consequently, PCOC data used in the screen were extracted from the Rocky Flats Environmental Database System (RFEDS). All data collected matched location codes used by the contractor that initially identified the PCOCs.

N3.2.8.1 Data Review and Cleanup

Analytical data used in this report were extracted for the period January 1990 through March 1995 from RFEDS. In addition to the analytical data from environmental samples, RFEDS includes information such as field QC samples and analytical results for sample dilutions.

Data were received in electronic format from RFEDS and systematically reviewed and organized to achieve a standard format for each record. These routines are based in part on guidance received from EG&G (EG&G 1994c) (Figure N3-8). Prior to data evaluation, the database was edited and made internally consistent by the following steps:

- Records reported with undefined units, laboratory qualifiers, or validation codes; blank results or unit fields; and nonradionuclide results equal to zero were researched. If a resolution was not possible, these records were labeled as unusable.
- Tentatively identified compound (TIC) records were labeled based on a result type or secondary result type of "TIC," or laboratory qualifier of "A" or "N."
- RFEDS assigned "Z" to the following sample records:
 - Samples analyzed at onsite laboratories
 - Geophysical samples
 - Sample numbers starting with NP (for National Pollutant Discharge Elimination System) or VW (for surveillance surface water)
 - All laboratory QA records that are typically stored in a separate RFEDS database
 - Records with a blank result field and information in the laboratory disposition field
 - Records assigned a validation code of "Z" were removed from the database
- Result values were converted to consistent units of measurement for each group of analytes for each media type.

Matrix	Analytical Group	Units
Soil	Metals and Water-Quality Parameters	milligrams per kilogram
	Radionuclides	picocuries per gram
	VOCs and SVOCs	micrograms per kilogram
Water	Radionuclides	picocuries per liter
	All other analytical groups	micrograms per liter

- A usability category was assigned based on validation codes and laboratory qualifiers (Table N3-18; Attachment 3, Tables 1 and 2).
- Results that indicated detection of an analyte and results that indicated nondetections were labeled. Metals, water-quality parameters, VOC, and semivolatile organic compound (SVOC) records with laboratory qualifiers of U, UC, UE, UJ, UN, UW, and UX were labeled “nondetections.” All records for radionuclides were labeled “detections” regardless of laboratory qualifier.
- The reported detection limit was checked against the contract-required detection limit (CRDL) specified in the General Radiochemistry and Routine Analytical Services Protocol (GRRASP). If these two values were equal, the value stored in the result field was used as the instrument detection limit (IDL) for metals or the method detection limit (MDL) for SVOC and VOC records.

An internally consistent database of supportable data, with standardized units of measurement, was developed using these cleanup steps. Detection and nondetection criteria, quantity summaries, validation status, and usability status of the records were compiled from this database.

The following additional formatting steps were performed to produce the final sitewide ERA database:

- Records for duplicate samples, field blanks, trip blanks, and equipment rinses were copied to the QC database.
- TIC records were removed.
- Records assigned a “Z” validation code were removed.
- Records labeled as unusable or rejected were removed.

In the resulting database, duplicate records were identified and researched to determine which record to use based on the result type (for example, TRG [target], DIL [dilution], REP [replicate], REX [re-extraction]), laboratory qualifier, and

validation code. Records not used were removed and stored. The following criteria were used interactively to identify the most accurate record:

- If none of the records was validated, the TRG record was kept and the other(s) was removed.
- If one record was validated and the other(s) was not, the validated record was kept and the other(s) was removed.
- If more than one record was validated, the record with the highest "rank" in the validation code hierarchy was kept and the other(s) was removed.

Validation Code Hierarchy	
V	Highest
A, JA	Second Highest
Y, blank	Third Highest

- If the records had the same validation code, the record with highest concentration (to be most conservative) was kept and the other(s) was removed.

Source area designations were assigned based on whether or not each location fell within the boundaries of a given source area.

The resulting final database was subdivided into the following media-specific databases: biota, sediment, surface soil, surface water, subsurface soil, and groundwater.

N3.2.8.2 Summary Statistics

Summary statistics were calculated for each medium by source area and analyte. For each of the PCOCs in each of the media-specific databases, mean concentration, UCL_{95} of the mean concentration (1-tailed upper 95 percent confidence limit of the true mean), maximum detected concentration, detection frequency, and standard deviation were calculated.

Prior to performing statistical comparisons, data from the working database were systematically reviewed to identify records for nondetections. A new result value was assigned to the nondetection records for use in statistical summaries or comparison tests. In statistical summaries (mean, standard deviation, etc.), this value is either one-half the reported detection limit when the IDL or MDL is reported or one-half the result when the CRDL is reported (EG&G 1994c). In the statistical comparison tests, this value is the reported detection limit (Gilbert 1993).

The UCL_{95} was selected as a reasonable upper bound estimate of the exposure-point concentration. However, the UCL_{95} is sensitive to large variances sometimes produced by small sample size or varying detection limits. Large variances can cause the UCL_{95} to exceed the maximum detected concentration. The exposure-point concentration was created to address this potential problem and identified as the lesser of two values— UCL_{95} or the maximum detected concentration.

Background abiotic summary statistics were obtained from the Statistical Applications Group at EG&G. These data were recommended and approved by EPA. Biotic background summary statistics were calculated from data gathered in support of RFI/RI activities.

N3.3 Results of Preliminary Exposure Screen

The combined list of sitewide PCOCs was screened using methods described in Sections N3.1 and N3.2. Results from the risk screen were compiled and presented to EPA, EG&G, and DOE on May 31, 1995. Results of the preliminary risk screen were reviewed with EPA in a meeting on June 5, 1995. As a result of this meeting, ECOCs were identified and adjustments made in the screening calculations. Results of the preliminary risk screen are briefly described in the following subsections. Detailed results are presented in Attachments 4 through 6. A summary that lists the number of analytes with HQs greater than 1 for each source area having HIs greater than 1 is presented in Table N3-19.

ECOC screens were conducted for the three wide-ranging species (coyote, mule deer, and red-tailed hawk) and the four receptors with more restricted home ranges (limiting species). Risk for wide-ranging species was negligible; no HQs or HIs were greater than 1. No exposure risk estimate for any of the wide-ranging species resulted in a source area HQ or HI greater than 1. ECOCs were identified for the more limiting species and aquatic receptors that may spend most of their time in small areas and, therefore, are potentially in more frequent contact with contaminants (Table N3-20).

ECOCs were identified for each receptor and source area according to the following criteria (Figure N3-9). Analyte must:

- have HQ greater than or equal to 1
- be a PCOC in the relevant OU for each source area
- not be an essential nutrient (such as magnesium or zinc)

- have detection frequencies adequate to describe contamination. (This decision made on a consensus basis with EPA and DOE representatives. See meeting minutes for June 5, 1995)

PCOCs associated with an HQ greater than 1, but not included in the final list of ECOCs are listed in Table N3-21. The rationale for not including each analyte is also presented. The final list of ECOCs to be analyzed further in the risk characterization (Sections N4 and N5) is presented in Tables N3-20 and N3-22.

Results of exposure and risk estimates are described separately for aquatic organisms, wildlife, and vegetation. The risk estimate for each receptor group is described on sitewide (HI_{total} and HQ_{mean}), watershed ($HI_{watershed}$), and source area ($HI_{source\ area}$, $HQ_{source\ area}$) bases.

ECOCs were identified for all source areas except OU1 881 Hillside, OU5 Surface Disturbance, OU6 Burial Trenches, OU10 Outside Closures, and OU11 West Spray Field (Figures N3-2 and N3-3). However, little data were available for estimating exposures in these source areas.

ECOCs and preliminary risk calculations are described below by receptor and source area. Data are presented for source areas in order of descending risk.

N3.3.1 Aquatic Organisms

Risk to aquatic life was primarily due to organic contaminants in sediments. Risk from surface water PCOCs was limited to a small number of inorganic chemicals and was of low magnitude.

N3.3.1.1 Sediments

Sediments	HI_{mean}
$HI_{Walnut\ Creek\ watershed}$	260
$HI_{Woman\ Creek\ watershed}$	2.3

Preliminary risk calculations were made on the basis of individual ponds and stream segments to clearly identify contaminant sources. The HI for exposure of aquatic life to sediments ranged from 1.3 in Woman Creek to 35,000 in Pond A-2, indicating extreme variability in potentially toxic conditions. PCOCs contributing the most to risk estimates are PAHs and PCBs with HQs greater than 100. Silver is the primary inorganic ECOC, with concentrations that greatly exceeded aquatic life TRVs (Attachment 1, Tables 1 through 4).

A-Ponds (Attachment 4, Table 1)**Pond A-1: HI = 160**

Anthracene, chrysene, and benzo(b)fluoranthene had HQs of 89, 34, and 18, respectively. Other ECOCs in Pond A-1 had HQs between 1 and 10; these analytes included antimony, magnesium, toluene, cobalt, vanadium, Aroclor-1254, and benzo(k)fluoranthene.

Pond A-2: HI = 17

No ECOCs have HQs greater than 10. Analytes with HQs between 1 and 10 were chrysene, magnesium, aldrin, zinc, benzoic acid, cobalt, acetone, and vanadium.

Pond A-3: HI = 59

Chrysene and benzo(b)fluoranthene had HQ values of 29.1 and 18.3, respectively. Other ECOCs with HQs between 1 and 10 included antimony, magnesium, vanadium, cobalt, and zinc.

Pond A-4: HI = 13

No ECOCs had HQs greater than 10. Analytes with HQs between 1 and 10 were antimony, magnesium, vanadium, and cobalt.

Pond A-5: HI = 16

No ECOCs had HQs greater than 10. Analytes with HQs between 1 and 10 were benzoic acid, acetone, cobalt, magnesium, and vanadium.

B-Ponds (Attachment 4, Table 2)**Pond B-1: HI = 2,000**

Fluorene, anthracene, chrysene, silver, benzo(b)fluoranthene, and heptachlor had HQs ranging from 13 to 1,438. ECOCs with HQs less than 10 and greater than 1 included Aroclor-1254, zinc, methylene chloride, benzo(k)fluoranthene, copper, acetone, magnesium, cobalt, dibenzo(ah)anthracene, and vanadium.

Pond B-4: HI = 250

Anthracene, chrysene, benzo(b)fluoranthene, and silver had HQs ranging from 15 to 105. Other ECOCs with HQs less than 10 and greater than 1 included antimony, gamma-BHC (Lindane), magnesium, benzo(k)fluoranthene, vanadium, Aroclor-1254, zinc, and cobalt.

Pond B-3: HI = 130

Silver, chrysene, and benzo(b)fluoranthene had HQs ranging from 18 to 63. Most other ECOCs in Pond B-3 had HQs less than 10 and greater than 1; these analytes included antimony, Aroclor-1254, copper, magnesium, zinc, cobalt, and vanadium.

Pond B-2: HI = 74

Silver has an HQ of 52. Other ECOCs had HQs less than 10 and greater than 1; these analytes were chrysene, Aroclor-1254, magnesium, acetone, cobalt, manganese, and vanadium.

Pond B-5: HI = 8.1

ECOCs in Pond B-5 that had HQs less than 10 and greater than 1 were magnesium, vanadium, and cobalt.

The Walnut Creek watershed risk characterization was focused on several aspects, including the spatial distribution, possible toxic effects, and appropriateness of calculated benchmarks for PCBs and PAHs. The aquatic community in ponds and streams within the Walnut Creek watershed was also evaluated for apparent effects of ecotoxicity.

Walnut Creek (Attachment 4, Table 3)

South Walnut Creek: HI = 230

Anthracene, chrysene, benzo(b)fluoranthene, and methylene chloride had HQs greater than 10, ranging from 17 to 138. ECOCs that had HQs less than 10 and greater than 1 were zinc, benzo(k)fluoranthene, magnesium, benzoic acid, vanadium, barium, strontium, and cobalt.

North Walnut Creek: HI = 180

Anthracene, chrysene, and benzo(b)fluoranthene had HQs ranging from 15 to 107. ECOCs that had HQs less than 10 and greater than 1 were methylene chloride, benzoic acid, magnesium, barium, cobalt, vanadium, manganese, strontium, and acetone.

Woman Creek (Attachment 4, Table 4)

Pond C-2: HI = 3.0

Benzoic acid and zinc were the only ECOCs with HQs greater than 1 (1.7 and 1.3, respectively).

Pond C-1: HI = 2.6

Benzoic acid was the only ECOC with an HQ greater than 1 (HQ = 2.6).

The focus for the risk characterization on the Woman Creek watershed is limited due to the relatively small HQs and HIs. The benzoic acid sediment benchmark and the aquatic community are evaluated in relation to watershed management practices.

N3.3.1.2 Surface Water

Surface Water	Mean
HI _{total}	30
HI _{Walnut Creek}	33
HI _{Woman Creek}	32

As described in Section N3.2.7, preliminary risk calculations were made using only the PCOCs for each relevant OU. Therefore, the HI does not include PCOCs that were not relevant to the source area analyzed. Barium was the only ECOC in each source area analyzed, ranging from 13 in OU6 B-Ponds to 45 in OU7 Downgradient (Attachment 4, Table 5). Barium was the only surface water ECOC in the following source areas:

Source Area	Barium HQ	HI _{source area}
OU7 Downgradient	45	49
OU5 Old Landfill	37	38
OU5 C-Ponds	24	26
OU5 Ash Pits	17	18

There are no aquatic-life-based surface water standards available for barium. The Safe Drinking Water Act (SDWA) set the barium maximum contaminant level (MCL) and maximum contaminant level goal (MCLG) at 2,000 µg/l for human consumption. IRIS reported a human NOAEL of 10 mg/l. The Clean Water Act's

AWQC chose not to set barium standards for aquatic organisms. Soluble and toxic forms of barium in freshwater or marine ecosystems were thought unlikely due to the physical and chemical properties of barium. Therefore, EPA chose not to set freshwater or marine AWQC.

The aquatic barium standard used in the previous screen (May 1995) was not a regulatory standard and was the only aquatic-life-based standard available. However, this standard was calculated as a Tier II secondary chronic value by Suter and Mabrey (1994) as described in the Proposed Water Quality Guidance for the Great Lakes System (EPA 1993c). This calculation was inappropriate considering barium is not believed to be toxic to aquatic life under freshwater conditions likely to occur.

N3.3.2 Wildlife

Preliminary risk calculations for wildlife species are summarized in the following sections. Exposure estimates are presented in the tables and figures in Attachment 5. Analytes that were not included in the wildlife screen and reasons for their omission (such as, no TRV available or limited abiotic data available) are listed in the tables in Attachment 5.

As noted, the HI total for each wide-ranging species was less than 10, as follows: mule deer - 4.22, coyote - 1.78, and red-tailed hawk - 4.35, and no individual exceeded 0.05. Therefore, no ECOCs were identified for wide-ranging species.

The HI source areas for limiting species were greater than 1, suggesting that the potential for ecotoxic exposure is not negligible (Figures N3-10 and N3-11). However, conservative assumptions were used to estimate exposure, and risk may be overestimated. Conservative assumptions were reassessed in the risk characterization for ECOCs (Sections N4 and N5).

N3.3.2.1 Limiting Species

Preble's Meadow Jumping Mouse

Preble's Meadow Jumping Mouse	Mean
HI _{total}	5.40
HI _{Walnut Creek}	5.66
HI _{Woman Creek}	5.17

PMJM was selected to represent small mammals because of its omnivorous diet and special legal status. However, risk estimates may be extrapolated to other species. The potential risk to PMJM at RFETS is consistent across source areas (Figure N3-12), with HIs ranging from 8.10 in OU4 Downgradient to 0.72 in the OU2 Mound Area.

OU7 Downgradient and OU6 North Spray Field were the only source areas with ECOCs with HQ greater than 1 (selenium and barium).

OU7 Downgradient: HI = 6.47

Selenium contributes 36.46 percent of the total risk in the OU7 Downgradient area (HQ = 2.36); most of the exposure is due to ingestion of vegetation with high selenium concentrations.

OU6 North Spray Fields: HI = 6.38

Barium contributes 16.48 percent of the total risk in OU6 North Spray Fields (HQ = 1.05). Most of the barium intake was due to ingestion of vegetation with high barium concentrations.

Further risk characterization focused on refining risk and toxicity estimates of barium and selenium to PMJM. Spatial distributions of potentially ecotoxic vegetation were also characterized (Sections N4 and N5).

American Kestrel

American Kestrel	Mean
HI _{total}	6.70
HI _{Walnut Creek}	8.48
HI _{Woman Creek}	7.50

OU2 East Trenches and OU6 B-Ponds source areas had the highest HIs of 24.71 and 17.39, respectively. OU6 A-Ponds, OU6 Soil Dump Area, OU2 903 Pad, OU1 881 Hillside, OU5 Ash Pits, OU5 Old Landfill, OU7 Downgradient, OU11 West Spray Field, OU2 Mounds Area, OU5 C-Ponds, and OU6 Burial Trenches also had HIs greater than 1. Mercury, chromium, lead, and vanadium were the ECOCs for the American kestrel at RFETS (Figure N3-13).

OU2 East Trenches: HI = 24.71

Chromium was the only ECOC in the East Trenches, contributing 17.65 percent of the total risk (HQ = 4.36). The primary source of intake was ingestion of terrestrial arthropods.

OU6 B-Ponds: HI = 17.39

Vanadium and lead were the only ECOCs, contributing 16.46 percent and 7.17 percent, respectively to the total risk (HQ = 2.86 and 1.25). For both chemicals, the potentially ecotoxic exposure was due to ingestion of small mammals. Mercury also had an HQ of 1. However, this analyte was not identified as an ECOC because (1) the preliminary risk estimate assumes 100 percent site use, (2) seasonal migration of kestrels reduces the contact with contaminated areas, and (3) only two of nine small mammal samples had mercury concentrations above the detection limit (see meeting minutes June 5, 1995). Therefore, the probability of a kestrel ingesting ecotoxic concentrations is minimal (EPA 1995a).

OU6 A-Ponds: HI = 12.51

Lead and chromium were the only ECOCs, contributing 14.03 percent and 10.63 percent, respectively of the total risk (HQ = 1.76 and 1.33). The risk of ecotoxic exposure to American kestrels was due to ingestion of small mammals. Zinc was also associated with an HQ greater than 1. However, zinc was not included in ECOCs for this source area because it is an essential nutrient (EPA 1995).

OU6 Soil Dump Area: HI = 11.07

Mercury was the only ECOC, contributing 28.39 percent of the total risk (HQ = 3.14). The primary exposure pathway was ingestion of small mammals.

OU2 903 Pad: HI = 10.78

Chromium was the only ECOC, contributing 51.54 percent of the total risk (HQ = 5.56). The primary exposure pathway was ingestion of terrestrial arthropods.

OU4 Downgradient: HI = 4.21

Mercury was the only ECOC, contributing 32.26 percent of the total risk (HQ = 1.36). The primary exposure pathway was ingestion of small mammals.

OU2 Mound Area: HI = 2.80

Chromium contributed 90.27 percent of the total risk (HQ = 2.53) in this source area. The primary exposure pathway was ingestion of terrestrial arthropods.

The risk characterization for American kestrels was focused on the bioavailability of ECOCs. The spatial distribution of potentially ecotoxic terrestrial arthropods and small mammals were also characterized. In addition, seasonal use and associated lower risks to the RFETS American kestrel population were assessed.

Great Blue Heron

Results of the exposure estimation indicate potentially significant risk in all source areas potentially used by great blue herons (Old Landfill, A-Ponds, B-Ponds, C-Ponds, 881 Hillside, and Ash Pits) (Figure N3-14). The HI_{mean} for all source areas was 17.92 with most risk due to mercury, antimony, and di-N-butyl phthalate (DBP).

Great Blue Heron	Mean
HI_{total}	17.92
$HI_{\text{Walnut Creek}}$	16.68
$HI_{\text{Woman Creek}}$	16.64

OU5 Old Landfill: HI = 41.23

Mercury and antimony were the only ECOCs, contributing 69.85 and 3.78, percent respectively, of the total exposure risk. Mercury had an HQ of 28.8, primarily from estimated concentrations in fish. Antimony had an HQ of 1.56 due to ingestion of contaminated sediment.

OU6 A-Ponds: HI = 23.50

The A-Ponds had an HI of 23.50, 70.45 percent of which was from estimated concentrations of DBP in fish tissues eaten by great blue herons (HQ = 16.36).

OU6 B-Ponds: HI = 18.70

DBP and mercury were the only ECOCs. DBP had an HQ of 8.27 (44.21 percent of the total risk), due to estimated concentrations in fish. Mercury had an HQ of 2.40, also from estimated concentrations in fish tissue, contributing 12.83 percent of the total risk.

OU5 C-Ponds: HI = 17.19

Mercury was the only ECOC in the C-Ponds, with an HQ of 6.40 from measured fish concentrations (37.24 percent of total risk). Copper also had an HQ greater than 1 (1.14) but was not identified as an ECOC because it does not bioaccumulate, and realistic seasonal use factors reduced the HQ to negligible risk levels.

Mercury, DBP, and antimony were included in the ECOCs because they had HQs greater than 1. PCBs appeared to be relatively non-toxic under current conditions but were included in the ECOCs because of their potential to bioaccumulate.

Preliminary risk calculations for the great blue heron were based on year-round residence at RFETS. As described in TM2 (DOE 1995a), great blue herons are common in summer, rare in spring and fall, and uncommon in winter. The risk characterizations focused on probabilistic estimation of risk and review of contaminant distribution.

Mallard

Mallard	Mean
HI _{total}	1.33
HI _{Walnut Creek}	2.22
HI _{Woman Creek}	0.63

Based on screening estimates, the OU6 A-Ponds, OU5 C-Ponds, and OU6 B-Ponds represent the highest risk of exposure to mallards (HI = 4.55, 1.67, and 1.60, respectively) (Figure N3-15). The HI total for the A, B, and C-Ponds was 7.82. DBP in surface water in the A-Ponds was the only PCOC with an HQ greater than 1 and was identified as an ECOC. DBP risk to mallards (43.92 percent of the total) was due to ingestion of benthic macroinvertebrates.

Risk characterization focused on characterizing potential for DBP bioconcentration in the aquatic prey species in each of the A-Ponds. Although current concentrations of PCBs did not result in HQs greater than 1, these PCOCs were included in ECOCs because of their potential bioconcentration in aquatic prey.

N3.3.2.2 Wide-Ranging Species

Coyote: Sitewide HI mean = 0.14

All source areas pose negligible risks to the coyote population at RFETS (Figure N3-16). The source areas contributing the most ecotoxic exposure potential were OU6 B-Ponds (HI = 0.44) and OU6 A-Ponds (HI = 0.32). Every analyte evaluated had an HQ less than 1, and the mean HQ (HQ_{mean}) was less than 0.05.

Mule Deer: Sitewide HI mean = 0.34.

All source areas pose negligible risk to the mule deer population at RFETS (Figure N3-17). The source area contributing the most ecotoxic exposure potential was OU2 903 Pad (HI = 0.88). Every analyte evaluated had an HQ less than 1, and the HQ mean was less than 0.05.

Red-tailed Hawk: Sitewide HI mean = 0.32

All source areas pose negligible risk to red-tailed hawks at RFETS (Figure N3-18). The source area contributing the most ecotoxic exposure potential was the OU6 B-Ponds (HI = 0.77). Every analyte evaluated had an HQ less than 1, and the HQ mean was less than 0.05.

Based on the preliminary exposure and risk calculations, the risk to wide-ranging species was negligible. Therefore, they were not further evaluated in the risk characterization (Section N4).

N3.3.3 Vegetation

N3.3.3.1 Subsurface Soil Phytotoxicity

The vegetation analysis portion of the preliminary risk screen estimated risk to vegetation from subsurface soil contamination (Attachment 6, Tables 2 through 6). No HQ values were greater than 10, except nitrate/nitrite with an HQ of 170 in the OU7 Downgradient Area. ECOCs with HQs between 1 and 10 included the following metals: chromium, nickel, zinc, copper, silver, strontium, antimony, lead, vanadium, and cadmium. Each of these analytes was included in the subsurface soil ECOCs for vegetation.

N3.3.3.2 Sediment Phytotoxicity

Potential risk to vegetation growing in wetland or riparian areas were assessed using sediment exposure-point concentrations compared with phytotoxicity TRVs (Attachment 6, Table 6). No HQ values were greater than 10 except the following:

silver and zinc in Pond B-1 and silver in Ponds B-2, B-3, and B-4. ECOCs with HQs between 1 and 10 included the following metals: antimony, chromium, mercury, strontium, vanadium, and zinc.

HIs were not applicable to vegetation communities. Exposure risk to vegetation was estimated on an individual phytotoxic basis because of the inability of plants to move and the patchiness of the contaminant distribution. Thus, each plant was not likely to come into contact with all contaminants within each source area.

Further risk characterization for vegetation communities focused on ECOC distribution within the source areas. If ECOC concentrations were found to be elevated only in limited portions of the source area, those portions were assessed for toxic effects on the vegetation community.

It should be noted that benchmarks were unavailable for many PCOCs because of the lack of phytotoxicological research on these contaminants. In addition, the diversity of soils, plant species, and chemical forms require the use of site-specific vegetation benchmarks (Will and Suter 1994). The concentrations of PCOCs for which TRVs were lacking are presented in Attachment 6, Tables 7 and 8. These exposures may be re-evaluated later when more toxicity information becomes available.

N3.3.4 Burrow Air Exposure Screen

Small Mammals	Inhalation Risk
HI _{OU2 903 Pad}	1.88×10^3
HI _{OU2 East Trenches}	19.6
HI _{OU2 Mound Area}	0.567
HI _{OUS Old Landfill}	0.886
HI _{mean}	475

Subsurface soil concentrations were screened using inhalation TRVs to determine the potential for risk to small mammals burrowing in the soils known to have high VOC concentrations (Attachment 6, Table 9).

No HQ values were greater than 10, except toluene, with an HQ of 19.6 in the OU2 East Trenches, and 1,880 in the OU2 903 Pad.

It should be noted that benchmarks were unavailable for many PCOCs because of the lack of phytotoxicological research on these contaminants. The concentrations of PCOCs for which TRVs were lacking are presented in Attachment 6, Table 10.

These exposures may be re-evaluated later, when more toxicity information becomes available.

Further risk characterization for small mammal inhalation risk focused on toluene distribution within the source areas as well as detection frequency and data quality.

N3.3.5 Radionuclides Ecotoxic Exposure Screen

Sitewide surface soil, surface water, and sediment maximum PCOC concentrations were compared against the radionuclide benchmarks (Higley and Kuperman 1995) (Attachment 6, Tables 11, 12, and 15). Sediment and surface water HI_{sitewide} were 0.02 and 0.46, respectively. The surface soil HI_{sitewide} was 28.2, indicating that ecotoxic exposure may not be negligible. PCOCs with HQs greater than 1 were plutonium-239/240, uranium-233/234, and uranium-238.

Plutonium-239/240: Sitewide maximum HQ was 1.92 (OU2 903 Pad surface soils).

Uranium-233/234: Sitewide maximum HQ was 1.56 (OU5 Old Landfill surface soil).

Uranium-238: Sitewide maximum HQ was 23.8 (OU5 Old Landfill surface soil).

As described in Section N3.2.7, surface soil radionuclide TRVs were based on the bounding exposure of small mammals. Higley and Kuperman (1995) chose small mammals as limiting species based on their radionuclide sensitivity, small home ranges, and continuous contact with soil.

Further risk characterization focused on the radionuclide doses to small mammals and raptor species ingesting small mammals at RFETS. Body burdens required for critical doses were compared with RFETS data to evaluate the risks from radionuclides accumulating through the biological pathways.

The ECOCs chosen for further evaluation are americium-241, plutonium-239/240, radium-228, uranium-233/234, and uranium-238.

N3.4 Focus for Risk Characterization

The final ECOC list (Tables N3-20, N3-22, and N3-23) defines the analytes that will be further evaluated in Sections N4 and N5. Source areas, receptors at risk, exposure points, and ECOCs are defined in Tables N3-24 and N3-25.

CHAPTER N3

TABLES

Table N3-1
Analytes Omitted from the PCOC List

Analytes	Justification/Reason
Bicarbonate as CaCO ₃	Not expected to be toxic
Calcium	Essential nutrient
Carbonate as CaCO ₃	Not expected to be toxic
Chloride	Essential nutrient
Gross alpha	Indicator parameter; individual radionuclides were analyzed separately
Gross beta	Indicator parameter; individual radionuclides were analyzed separately
Iron	Essential nutrient
Magnesium	PCOC only for aquatic life
Orthophosphate	Not expected to be toxic
Potassium	Essential nutrient
Silicon	Not expected to be toxic
Sodium	Essential nutrient
Sulfate	Not expected to be toxic
Sulfide	Not expected to be toxic
Total dissolved solids	Not expected to be toxic

**Table N3-2
Sitewide Wildlife PCOC List**

Analyte	Group	OU PCOCs
Aluminum	M	7
Antimony	M	5,6,7
Arsenic	M	6,7
Barium	M	5,6,7
Beryllium	M	4,7
Cadmium	M	4
Chromium	M	2,6,7
Cobalt	M	5,6,7
Copper	M	5,6,7
Lead	M	2,5,6,7
Lithium	M	5,7
Magnesium	M	6,7
Manganese	M	6,7
Mercury	M	4,5,6
Molybdenum	M	6,7
Nickel	M	6,7
Selenium	M	7
Silver	M	4,5,6
Strontium	M	5,6,7
Thallium	M	7
Tin	M	7
Vanadium	M	6,7
Zinc	M	5,6,7
4,4'-DDT	P	2,5
Aldrin	P	5,6
Aroclor-1248	P	1
Aroclor-1254	P	1,2,4,5,6
Aroclor-1260	P	2,6
delta-BHC	P	2
Dieldrin	P	5
Endosulfan sulfate	P	5
Endrin ketone	P	5
gamma-BHC (Lindane)	P	6
Heptachlor	P	6
Heptachlor epoxide	P	5
Methoxychlor	P	5
Americium-241	R	1,2,4,5,6,7
Cesium-134	R	4
Cesium-137	R	6,7
Plutonium-239/240	R	1,2,4,5,6
Radium-226	R	2,6,7
Radium-228	R	6
Strontium-89/90	R	2,6,7
Tritium	R	4,5,6,7
Uranium-233/234	R	1,2,4,5,6
Uranium-235	R	1,2,4,5,6,7
Uranium-238	R	1,2,4,5,6,7
1,2,4-Trichlorobenzene	S	6
2-Methylnaphthalene	S	5,6
Acenaphthene	S	1,5,6,7

**Table N3-2
Sitewide Wildlife PCOC List**

Analyte	Group	OU PCOCs
Acenaphthylene	S	1,5
Anthracene	S	1,5,6,7
Benzo(a)anthracene	S	1,2,4,5,6,7
Benzo(a)pyrene	S	1,2,4,5,6,7
Benzo(b)fluoranthene	S	1,2,4,5,6,7
Benzo(ghi)perylene	S	1,2,4,5,6,7
Benzo(k)fluoranthene	S	1,2,4,5,6,7
Benzoic acid	S	2,5,6,7
Benzyl alcohol	S	6
Bis(2-chloroisopropyl)ether	S	7
Bis(2-ethylhexyl)phthalate	S	2,4,5,6,7
Butyl benzyl phthalate	S	5,6
Chrysene	S	1,2,4,5,6,7
Di-N-butyl phthalate	S	2,4,5,6,7
Di-N-octyl phthalate	S	5,6
Dibenzo(a,h)anthracene	S	1,5,6
Dibenzofuran	S	5,6
Fluoranthene	S	1,2,4,5,6,7
Fluorene	S	1,5,6,7
Indeno(1,2,3-cd)pyrene	S	1,2,4,5,6,7
Isophorone	S	5
Naphthalene	S	1,5,6
Pentachlorophenol	S	5
Phenanthrene	S	1,2,4,5,6,7
Phenol	S	5,6
Pyrene	S	1,2,4,5,6,7
1,1,1-Trichloroethane	V	1
1,1-Dichloroethane	V	1
1,1-Dichloroethene	V	1
1,2-Dichloroethane	V	1,6
1,2-Dichloroethene	V	1,6
2-Butanone	V	6,7
4-Methyl-2-pentanone	V	6
Acetone	V	6,7
Benzene	V	6
Chloroform	V	6
Methylene chloride	V	5,6,7
Tetrachloroethene	V	1,6
Toluene	V	1,5,6,7
Total xylenes	V	1
Trichloroethene	V	1,6
Vinyl acetate	V	7
Nitrate/Nitrite	W	4,7

M - Metal

P - Pesticide, polychlorinated biphenyl (PCB), or herbicide

R - Radionuclide

S - Semivolatile organic compound

V - Volatile organic compound

W - Water quality parameter

**Table N3-3
Sitewide Vegetation PCOC List**

Analyte	Group	OU PCOCs
Aluminum	M	7
Antimony	M	5
Arsenic	M	2,7
Barium	M	2,4,5,6,7
Beryllium	M	5
Cadmium	M	2,4,5
Chromium	M	2,5,6,7
Cobalt	M	2,5,7
Copper	M	2,5,7
Lead	M	2,5,6,7
Lithium	M	4
Manganese	M	2,4,7
Mercury	M	2
Molybdenum	M	5
Nickel	M	5,7
Selenium	M	7
Silver	M	2,5
Strontium	M	6,7
Vanadium	M	6
Zinc	M	2,4,5,6,7
4,4'-DDT	P	2
alpha-BHC	P	5
Aroclor-1254	P	2,5
Aroclor-1260	P	5
Heptachlor epoxide	P	5
Americium-241	R	1,2,4,5,6,7,11
Cesium-134	R	4
Cesium-137	R	2,4,7
Plutonium-239/240	R	1,2,4,5,6,11
Radium-226	R	2,4,7
Radium-228	R	2,7
Strontium-89/90	R	2,4,7
Tritium	R	2,4,7,11
Uranium-233/234	R	1,2,4,5,6
Uranium-235	R	1,2,4,5,6,7
Uranium-238	R	1,2,4,5,6,7
1,4-Dichlorobenzene	S	2,6
2-Chlorophenol	S	6
2-Methylnaphthalene	S	1,2,5
2-Methylphenol	S	2
4-Methylphenol	S	2
4-Nitroaniline	S	2
Acenaphthene	S	1,2,5,6
Acenaphthylene	S	5
Anthracene	S	1,2,5
Benzo(a)anthracene	S	1,2,5,6,7
Benzo(a)pyrene	S	1,2,5,6
Benzo(b)fluoranthene	S	1,2,5,6
Benzo(ghi)perylene	S	1,2,5
Benzo(k)fluoranthene	S	1,5,6
Benzoic acid	S	2,5,6

Table N3-3
Sitewide Vegetation PCOC List

Analyte	Group	OU PCOCs
Bis(2-ethylhexyl)phthalate	S	2,4,5,6,7
Butyl benzyl phthalate	S	2,5,7
Chrysene	S	1,2,5,6,7
Di-N-butyl phthalate	S	2,4,5
Di-N-octyl phthalate	S	2,6,7
Dibenzo(a,h)anthracene	S	1,5
Dibenzofuran	S	5
Diethyl phthalate	S	6
Fluoranthene	S	1,2,5,6,7
Fluorene	S	1,2,5
Hexachlorobutadiene	S	2
Hexachloroethane	S	2
Indeno(1,2,3-cd)pyrene	S	1,2,5,6
Isophorone	S	5
N-Nitrosodiphenylamine	S	2
Naphthalene	S	1,2,5
Pentachlorophenol	S	2,5,6
Phenanthrene	S	1,2,5,6,7
Phenol	S	5,6
Pyrene	S	1,2,5,6,7
1,1,1-Trichloroethane	V	1,2,5,7
1,1,2,2-Tetrachloroethane	V	2
1,1-Dichloroethene	V	1
1,2-Dichloroethane	V	1,2
1,2-Dichloroethene	V	2
2-Butanone	V	2,4,5,6
2-Chloroethyl vinyl ether	V	2
4-Methyl-2-pentanone	V	2,5,6,7
Acetone	V	2,4,5,6
Benzene	V	2,6
Carbon disulfide	V	2
Carbon tetrachloride	V	1,2
Chloroform	V	1,2,4,6
cis-1,3-Dichloropropene	V	2
Ethylbenzene	V	2,5
Methylene chloride	V	2,4,5,6,7
Styrene	V	2,6
Tetrachloroethene	V	1,2,5
Toluene	V	1,2,4,5,6,7
Total xylenes	V	1,2,5,6
Trichloroethene	V	1,2,5,6
Cyanide	W	4
Nitrate/Nitrite	W	2,4,7,11

M - Metal

P - Pesticide, polychlorinated biphenyl (PCB), or herbicide

R - Radionuclide

S - Semivolatile organic compound

V - Volatile organic compound

W - Water quality parameter

**Table N3-4
Sitewide Sediment PCOC List**

Analyte	Group	OU PCOCs
Aluminum	M	6
Antimony	M	6
Arsenic	M	6
Barium	M	6,7
Beryllium	M	7
Chromium	M	6,7
Cobalt	M	6
Copper	M	5,6,7
Lead	M	7
Magnesium	M	6,7
Mercury	M	5
Nickel	M	7
Selenium	M	7
Silver	M	6
Strontium	M	6,7
Vanadium	M	6,7
Zinc	M	5,6,7
Aldrin	P	6
Aroclor-1254	P	1,6
gamma-BHC (Lindane)	P	6
Heptachlor	P	6
Americium-241	R	1,5,6
Cesium-137	R	7
Plutonium-239/240	R	1
Radium-226	R	6
Radium-228	R	6
Strontium-89/90	R	6
Tritium	R	5,6
Uranium-233/234	R	5,6
Uranium-235	R	5,6
Uranium-238	R	5,6
1,2,4-Trichlorobenzene	S	6
2-Methylnaphthalene	S	6
4-Methyl-2-pentanone	S	6
Acenaphthene	S	6,7
Anthracene	S	6,7
Benzo(a)anthracene	S	6,7
Benzo(a)pyrene	S	6,7
Benzo(b)fluoranthene	S	1,6,7
Benzo(ghi)perylene	S	6,7
Benzo(k)fluoranthene	S	1,6,7
Benzoic acid	S	5,6,7
Benzyl alcohol	S	6
Bis(2-chloroisopropyl)ether	S	7
Bis(2-ethylhexyl)phthalate	S	6,7
Butyl benzyl phthalate	S	6
Chrysene	S	1,6,7
Di-N-butyl phthalate	S	5

**Table N3-4
Sitewide Sediment PCOC List**

Analyte	Group	OU PCOCs
Dibenzo(a,h)anthracene	S	6
Dibenzofuran	S	6
Fluoranthene	S	1,5,6,7
Fluorene	S	6,7
Indeno(1,2,3-cd)pyrene	S	6,7
Naphthalene	S	6
Phenanthrene	S	1,6,7
Phenol	S	5,6
Pyrene	S	1,6
1,1,1-Trichloroethane	V	1
2-Butanone	V	6,7
Acetone	V	7
Acetone	V	6,7
Benzene	V	6
Methylene chloride	V	6
Toluene	V	1,5,6,7

M - Metal

P - Pesticide, polychlorinated biphenyl (PCB), or herbicide

R - Radionuclide

S - Semivolatile organic compound

V - Volatile organic compound

**Table N3-5
Sitewide Surface Water PCOC List**

Analyte	Group	OU PCOCs
Antimony	M	7
Arsenic	M	7
Barium	M	5,7
Lead	M	6
Lithium	M	5,7
Magnesium	M	6,7
Manganese	M	7
Molybdenum	M	7
Nickel	M	7
Strontium	M	5,7
Thallium	M	7
Tin	M	7
Vanadium	M	7
Americium-241	R	1,5,7
Cesium-137	R	6
Plutonium-239/240	R	1
Strontium-89/90	R	6,7
Tritium	R	7
Uranium-233/234	R	5,6
Uranium-235	R	6,7
Uranium-238	R	5,6,7
Benzoic acid	S	5
Bis(2-ethylhexyl)phthalate	S	7
Di-N-butyl phthalate	S	6,7
Pentachlorophenol	S	5
1,1,1-Trichloroethane	V	1
1,1-Dichloroethane	V	1
1,1-Dichloroethene	V	1
1,2-Dichloroethane	V	1,6
1,2-Dichloroethene	V	1,6
Acetone	V	6,7
Chloroform	V	6
Methylene chloride	V	5,6,7
Tetrachloroethene	V	1,6
Toluene	V	1
Total xylenes	V	1
Trichloroethene	V	1,6
Vinyl acetate	V	7

M - Metal

P - Pesticide, polychlorinated biphenyl (PCB), or herbicide

R - Radionuclide

S - Semivolatile organic compound

V - Volatile organic compound

W - Water quality parameter

Table N3-6
Source Areas, Associated Operable Units, and IHSSs
in Walnut Creek and Woman Creek Watersheds

Operable Unit	ERA Source Area	IHSSs Included
Woman Creek Grassland		
OU5	Surface Disturbance	209
OU2	903 Pad Area	109, 112, 140, 183
	East Trenches	110, 111.1, 111.2, 111.3, 111.4, 111.5, 111.6, 111.7, 111.8, 216.2, 216.3
Riparian/Aquatic		
OU1	881 Hillside	102, 103, 104, 106, 107, 119.1, 119.2, 130, 145, 177
OU5	Ash Pits	133.1, 133.2, 133.3, 133.4, 133.5, 133.6
	Old Landfill	115
	C-Ponds	142.1, 142.11
Walnut Creek Grassland		
OU2	East Trenches	110, 111.1, 111.2, 111.3, 111.4, 111.5, 111.6, 111.7, 111.8, 216.2, 216.3
	Mound Area	108, 113, 153, 154
	903 Pad	109, 112, 140, 183
OU6	Soil Dump Areas	141, 156.2, 165, 216.1
OU6	Burial Trenches	166.1, 166.2, 166.3
	North Spray Field	167.1, 167.2, 167.3
OU7	Downgradient Areas	NA
OU10	Other Outside Closure	170, 174
OU11	West Spray Field	168
Riparian/Aquatic Units		
OU6	A-Ponds	142.1, 142.2, 142.3, 142.4, 142.12
OU6	B-Ponds	142.5, 142.6, 142.7, 142.8, 142.9

Table N3-7
Habitat Preferences and Primary Dietary Components for Key Receptor Species

Key Receptor Species	Habitat Preferences												Primary Dietary Components ¹				
Preble's Meadow Jumping Mouse American Kestrel Great Blue Heron Mallard Coyote Mule Deer Red-tailed Hawk	Open Water																grass seeds, insects, fruit
	Wet Meadow	X															invertebrates, small mammals, birds, reptiles
	Short Marsh		X														fish, amphibians, crustaceans
	Tall Marsh			X													invertebrates, plants
	Riparian Woodland	X	X	X	X	X											animals, plants
	Ponderosa Pine Woodland						X										shrubs and forbs; grasses during the spring
	Tree Plantings						X										lagomorphs, small mammals, birds, reptiles
	Riparian Shrubland	X						X									
Short Upland Shrubland		X						X									
Tall Upland Shrubland			X						X								
Short Grassland				X						X							
Mesic Mixed Grassland					X						X						
Xeric Mixed Grassland												X					
Reclaimed Grassland													X				
Disturbed Annual Grass/Forb														X			
Disturbed/Barren Land																	

¹Based on literature reviews summarized in TM2 (DOE 1995b), listed from largest to smallest component.

Table N3-8
Exposure Routes and Exposure Points for Key Receptors

Key Receptors	Exposure Routes	Exposure Points
Limiting Species		
Preble's Meadow Jumping Mouse	Ingestion	Surface soil Sediments Surface water Vegetation Terrestrial arthropods
	Inhalation	Air in burrows
American Kestrel	Ingestion	Surface soil Small mammals Terrestrial arthropods
Great Blue Heron	Ingestion	Surface water Sediment Fish
Mallard	Ingestion	Surface water Soil Sediments Fish Benthic macroinvertebrates Vegetation
Wide-Ranging Species		
Coyote	Ingestion	Surface soil Surface water Small mammals Vegetation
Mule Deer	Ingestion	Surface soil Surface water Vegetation
Red-tailed Hawk	Ingestion	Surface soil Small mammals
Other Receptors		
Vegetation	Direct contact	Subsurface soil
Aquatic Organisms	Direct contact	Surface water Sediment

Table N3-9
Biota Data Available

OU	Source Area Analyte Group	Small Mammals			Vegetation ¹			Terrestrial Arthropods			Fish ²			Benthic Macroinvertebrates ²		
		M	R	O	M	R	O	M	R	O	M	R	O	M	R	O
OU1	881 Hillside	X	X	—	X	X	C	X	X	—	B	X	C	C	—	C
OU2	903 Pad Area	X	X	—	X	X	C	X	X	—	C	—	C	C	—	C
OU2	East Trenches	X	X	—	X	X	C	X	—	—	INC	INC	INC	INC	INC	INC
OU2	Mound Area	X	—	—	—	—	C	X	—	—	INC	INC	INC	INC	INC	INC
OU4	Downgradient	X	X	—	X	X	C	—	—	—	INC	INC	INC	INC	INC	INC
OU5	Ash Pits	X	X	—	X	X	—	—	—	—	C	—	C	C	—	C
OU5	C-Ponds	X	X	—	X	X	C	X	X	—	B	X	B	B	X	C
OU5	Old Landfill	X	X	—	X	X	C	—	—	—	C	—	C	B	X	C
OU5	Surface Disturbance	—	—	—	—	—	—	—	—	—	INC	INC	INC	INC	INC	INC
OU6	A-Ponds	X	X	—	X	X	C	—	—	—	B	X	B	C	—	B
OU6	Burial Trenches	X	X	—	X	X	C	—	—	—	INC	INC	INC	INC	INC	INC
OU6	B-Ponds	X	X	—	X	X	B	—	—	—	B	X	B	C	—	B
OU6	Soil Dump Areas	X	X	—	X	X	C	—	—	—	INC	INC	INC	INC	INC	INC
OU6	North Spray Field	—	—	—	X	X	C	—	—	—	INC	INC	INC	INC	INC	INC
OU7	Downgradient Areas	X	X	—	X	X	C	—	—	—	INC	INC	INC	INC	INC	INC
OU10	Other Outside Closures	—	—	—	—	—	—	—	—	—	INC	INC	INC	INC	INC	INC
OU11	West Spray Field	—	—	—	—	—	C	—	—	—	INC	INC	INC	INC	INC	INC

¹Concentration of organic compounds in vegetation estimated from subsurface soil concentrations, using methods in Travis and Arms (1988).

²Concentration of metals and organics in fish and benthic macroinvertebrate tissue estimated from surface water concentrations, using bioconcentration factors (Lyman *et al.* 1982).

M - metals

R - radionuclide

O - organics

X - measured values

C - calculated value

B - both measured and calculated values

INC - incomplete pathway

— - unable to estimate concentrations

Table N3-10
Exposure Parameters for Preble's Meadow Jumping Mouse

Source Area	Source Area Size (hectares)	Intake Rate (kg/kg/day)				Site Use Factor					
		Terrestrial Arthropods	Vegetation	Sediment	Soil ¹	Surface Water ²	Terrestrial Arthropods	Vegetation	Sediment	Soil	Surface Water
OU1 881 Hillside	22.303	0.051	0.119	0.002	0.002	0.150	1.000	1.000	1.000	1.000	1.000
OU2 903 Pad	27.605	0.051	0.119	0.002	0.002	0.150	1.000	1.000	1.000	1.000	1.000
OU2 East Trenches	39.861	0.051	0.119	INC	0.004	INC	1.000	1.000	INC	1.000	INC
OU2 Mound Area	2.256	NR	0.170	INC	0.004	INC	1.000	1.000	INC	1.000	INC
OU4 Downgradient	6.370	NR	0.170	INC	0.004	INC	1.000	1.000	INC	1.000	INC
OU5 Ash Pits	19.080	NR	0.170	0.002	0.002	0.150	1.000	1.000	1.000	1.000	1.000
OU5 C-Ponds	12.759	0.051	0.119	0.002	0.002	0.150	1.000	1.000	1.000	1.000	1.000
OU5 Old Landfill	13.532	NR	0.170	0.002	0.002	0.150	1.000	1.000	1.000	1.000	1.000
OU6 A-Ponds	12.828	NR	0.170	0.002	0.002	0.150	1.000	1.000	1.000	1.000	1.000
OU6 B-Ponds	8.473	NR	0.170	0.002	0.002	0.150	1.000	1.000	1.000	1.000	1.000
OU6 Burial Trenches	1.040	NR	0.170	INC	NR	INC	1.000	1.000	INC	1.000	INC
OU6 North Spray Field	4.397	NR	0.170	INC	0.004	INC	1.000	1.000	INC	1.000	INC
OU6 Soil Dump Areas	18.038	NR	0.170	INC	0.004	INC	1.000	1.000	INC	1.000	INC
OU7 Downgradient Areas	2.764	NR	0.170	INC	0.004	INC	1.000	1.000	INC	1.000	INC
OU10 Outside Closures	2.690	NR	0.170	INC	NR	INC	1.000	1.000	INC	1.000	INC
OU11 West Spray Field	45.953	NR	0.170	INC	0.004	INC	1.000	1.000	INC	1.000	INC

¹ Soil ingestion rates from Attachment 1, Table 3

² Surface water ingestion rates from DOE 1995b

INC - incomplete pathway

NR - no data are available for this media

Preble's Meadow Jumping Mouse Information

Environmental media for which intakes were calculated: terrestrial arthropods, vegetation, sediment, soil, and surface water

Percent of diet represented: vegetation - 70%; terrestrial arthropods - 30% (DOE 1995b)

Total food ingestion rate: 0.17 kg/kg/day (DOE 1995b)

Home range: 0.365 ha (DOE 1995b)

Because home range < source area, all Site Use Factors = 1.000

Table N3-11
Exposure Parameters for American Kestrel

Source Area	Source Area Size (hectares)	Intake Rate (kg/kg/day)			Site Use Factor		
		Small Mammals	Terrestrial Arthropods	Soil ¹	Small Mammals	Terrestrial Arthropods	Soil
OU1 881 Hillside	22.300	0.140	0.150	0.008	0.592	0.592	0.592
OU2 903 Pad	27.600	0.140	0.150	0.008	0.733	0.733	0.733
OU2 East Trenches	39.860	0.140	0.150	0.008	1.000	1.000	1.000
OU2 Mound Area	2.260	NR	NR	0.008	0.060	0.060	0.060
OU4 Downgradient	6.370	0.290	NR	0.008	0.172	0.172	0.172
OU5 Ash Pits	19.080	0.290	NR	0.008	0.502	0.502	0.502
OU5 C-Ponds	12.760	0.140	0.150	0.008	0.301	0.301	0.301
OU5 Old Landfill	13.530	0.290	NR	0.008	0.356	0.356	0.356
OU5 Surface Disturbance	1.660	NR	NR	0.008	0.044	0.044	0.044
OU6 A-Ponds	12.830	0.290	NR	0.008	0.287	0.287	0.287
OU6 B-Ponds	8.470	0.290	NR	0.008	0.208	0.208	0.208
OU6 Burial Trenches	1.040	0.290	NR	NR	0.028	0.028	0.028
OU6 North Spray Field	4.400	NR	NR	0.008	0.119	0.119	0.119
OU6 Soil Dump Areas	18.040	0.290	NR	0.008	0.496	0.496	0.496
OU7 Downgradient Areas	2.760	0.290	NR	0.008	0.075	0.075	0.075
OU10 Outside Closures	2.690	NR	NR	NR	0.071	0.071	0.071
OU11 West Spray Field	45.950	NR	NR	0.008	1.000	1.000	1.000

¹ soil ingestion rates from Attachment 1, Table 3

NR - no data are available for this media

American Kestrel Information

Environmental media for which intakes were calculated: small mammals, terrestrial arthropods, birds, and soil

Percent of diet represented: terrestrial arthropods - 51%; small mammals - 49% (DOE 1995b)

Assumes raptors do not drink surface water; all water needs are met through metabolism of prey

Total food ingestion rate: 0.29 kg/kg/day (DOE 1995b)

Home range: 38 ha (DOE 1995b)

Refer to Attachment 1, Table 6 for Site Use Factor calculation methods for American Kestrel

Table N3-12
Exposure Parameters for Great Blue Heron

Source Area	Source Area Size (hectares)	Intake Rate (kg/kg/day)			Site Use Factor		
		Fish	Sediment	Surface Water ¹	Fish	Sediment	Surface Water
OU1 881 Hillside	22.300	0.180	0.004	0.045	1.000	1.000	1.000
OU2 903 Pad	27.600	0.180	0.004	0.045	1.000	1.000	1.000
OU5 Ash Pits	19.080	0.180	0.004	0.045	1.000	1.000	1.000
OU5 C-Ponds	12.760	0.180	0.004	0.045	1.000	1.000	1.000
OU5 Old Landfill	13.530	0.180	0.004	0.045	1.000	1.000	1.000
OU6 A-Ponds	12.830	0.180	0.004	0.045	1.000	1.000	1.000
OU6 B-Ponds	8.470	0.180	0.004	0.045	1.000	1.000	1.000

¹ Surface water ingestion rates from DOE 1995b

Great Blue Heron Information

Environmental media for which intakes were calculated: fish, sediment, and surface water

Percent of diet represented: fish - 100% (DOE 1995b)

Total food ingestion rate: 0.18 kg/kg/day (DOE 1995b)

Home range: 4.5 ha (DOE 1995b)

Because home range < source area, all Site Use Factors = 1.000

Table N3-13
Exposure Parameters for Mallard

Source Area	Source Area Size (hectares)	Intake Rate (kg/kg/day)					Site Use Factor						
		Benthic Macroinvertebrates		Vegetation	Sediment	Soil ¹	Surface Water ²	Benthic Macroinvertebrates		Vegetation	Sediment	Soil	Surface Water
OU1 881 Hillside	22.300	0.039		0.013	0.001	0.001	0.056	0.032		0.032	0.032	0.039	0.032
OU2 903 Pad	27.600	0.039		0.013	0.001	0.001	0.056	0.014		0.014	0.014	0.048	0.014
OU5 Ash Pits	19.080	0.039		0.013	0.001	0.001	0.056	0.007		0.007	0.007	0.034	0.007
OU5 C-Ponds	12.760	0.039		0.013	0.001	0.001	0.056	0.165		0.165	0.165	0.019	0.165
OU5 Old Landfill	13.530	0.039		0.013	0.001	0.001	0.056	0.081		0.081	0.081	0.023	0.087
OU6 A-Ponds	12.830	0.039		0.013	0.001	0.001	0.056	0.428		0.428	0.428	0.017	0.428
OU6 B-Ponds	8.470	0.039		0.013	0.001	0.001	0.056	0.204		0.204	0.204	0.012	0.204

¹ Soil ingestion rates from Attachment 1, Table 3

² Surface water ingestion rates from DOE 1995b

Mallard Information

Environmental media for which intakes were calculated: benthic macroinvertebrates, vegetation, sediment, soil, and surface water
Percent of diet represented: benthic macroinvertebrates - 75%; vegetation - 25% (DOE 1995b)
Total food ingestion rate: 0.052 kg/kg/day (DOE 1995b)
Home range: 580 ha (DOE 1995b)
Refer to Attachment 1, Table 7 for Site Use Factor calculation methods for mallards

**Table N3-14
Exposure Parameters for Coyote**

Source Area	Source Area Size (hectares)	Intake Rate (kg/kg/day)			Site Use Factor				
		Small Mammals	Vegetation	Soil ¹	Surface Water ²	Small Mammals	Vegetation	Soil	Surface Water
OU1 881 Hillside	22.300	0.042	0.005	0.001	0.077	0.020	0.020	0.020	0.126
OU2 903 Pad	27.600	0.042	0.005	0.001	0.077	0.025	0.025	0.025	0.064
OU2 East Trenches	39.860	0.042	0.005	0.001	INC	0.036	0.036	0.036	INC
OU2 Mound Area	2.260	NR	0.047	0.001	INC	0.002	0.002	0.002	INC
OU4 Downgradient	6.370	0.042	0.005	0.001	INC	0.006	0.006	0.006	INC
OU5 Ash Pits	19.080	0.042	0.005	0.001	0.077	0.017	0.017	0.017	0.061
OU5 C-Ponds	12.760	0.042	0.005	0.001	0.077	0.010	0.010	0.010	0.192
OU5 Old Landfill	13.530	0.042	0.005	0.001	0.077	0.012	0.012	0.012	0.093
OU5 Surface Disturbance	1.660	NR	NR	0.001	INC	0.001	0.001	0.001	INC
OU6 A-Ponds	12.830	0.042	0.005	0.001	0.077	0.008	0.008	0.008	0.269
OU6 B-Ponds	8.470	0.042	0.005	0.001	0.077	0.006	0.006	0.006	0.164
OU6 Burial Trenches	1.040	0.042	0.005	NR	INC	0.001	0.001	0.001	INC
OU6 North Spray Field	4.400	NR	0.047	0.001	INC	0.004	0.004	0.004	INC
OU6 Soil Dump Areas	18.040	0.042	0.005	0.001	INC	0.016	0.016	0.016	INC
OU7 Downgradient Areas	2.760	0.042	0.005	0.001	INC	0.002	0.002	0.002	INC
OU10 Outside Closures	2.690	NR	0.047	NR	INC	0.002	0.002	0.002	INC
OU11 West Spray Field	45.950	NR	0.047	0.001	INC	0.041	0.041	0.041	INC

¹ Soil ingestion rates from Attachment 1, Table 3

² Surface water ingestion rates from DOE 1995b

INC - incomplete pathway

NR - no data are available for this media

Coyote Information

Environmental media for which intakes were calculated: small mammals, vegetation, sediment, soil, and surface water

Percent of diet represented: small mammals - 90%; vegetation - 10% (DOE 1995b)

Total food ingestion rate: 0.047 kg/kg/day (DOE 1995b)

Home range: 1130 ha (DOE 1995b)

Refer to Attachment 1, Table 9 for Site Use Factor calculation methods for coyotes

**Table N3-15
Exposure Parameters for Mule Deer**

Source Area	Source Area Size (hectares)	Intake Rate (kg/kg/day)		Site Use Factor		
		Vegetation	Soil ¹	Surface Water ²	Vegetation	Soil
OU1 881 Hillside	22.300	0.022	0.001	0.044	0.079	0.079
OU2 903 Pad	27.600	0.022	0.001	0.044	0.099	0.099
OU2 East Trenches	39.860	0.022	0.001	INC	0.143	0.143
OU2 Mound Area	2.260	0.022	0.001	INC	0.008	0.008
OU4 Downgradient	6.370	0.022	0.001	INC	0.023	0.023
OU5 Ash Pits	19.080	0.022	0.001	0.044	0.067	0.067
OU5 C-Ponds	12.760	0.022	0.001	0.044	0.039	0.039
OU5 Old Landfill	13.530	0.022	0.001	0.044	0.048	0.048
OU5 Surface Disturbance	1.660	NR	0.001	INC	0.006	0.006
OU6 A-Ponds	12.830	0.022	0.001	0.044	0.034	0.034
OU6 B-Ponds	8.470	0.022	0.001	0.044	0.025	0.025
OU6 Burial Trenches	1.040	0.022	NR	INC	0.004	0.004
OU6 North Spray Field	4.400	0.022	0.001	INC	0.016	0.016
OU6 Soil Dump Areas	18.040	0.022	0.001	INC	0.065	0.065
OU7 Downgradient Areas	2.760	0.022	0.001	INC	0.010	0.010
OU10 Outside Closures	2.690	0.022	NR	INC	0.010	0.010
OU11 West Spray Field	45.950	0.022	0.001	INC	0.161	0.161

¹ Soil ingestion rates from Attachment 1, Table 3

² Surface water ingestion rates from DOE 1995b

INC - incomplete pathway

NR - no data are available for this media

Mule Deer Information

Environmental media for which intakes were calculated: vegetation, soil, and surface water

Percent of diet represented: vegetation - 100% (DOE 1995b)

Total food ingestion rate: 0.022 kg/kg/day (DOE 1995b)

Home range: 285 ha (DOE 1995b)

Refer to Attachment 1, Table 8 for Site Use Factor calculation methods for mule deer

Table N3-16
Exposure Parameters for Red-tailed Hawk

Source Area	Source Area Size (hectares)	Intake Rate (kg/kg/day)		Site Use Factor	
		Small Mammals	Soil ¹	Small Mammals	Soil
OU1 881 Hillside	22.300	0.098	0.003	0.034	0.034
OU2 903 Pad	27.600	0.098	0.003	0.042	0.042
OU2 East Trenches	39.860	0.098	0.003	0.061	0.061
OU2 Mound Area	2.260	NR	0.003	0.003	0.003
OU4 Downgradient	6.370	0.098	0.003	0.010	0.010
OU5 Ash Pits	19.080	0.098	0.003	0.029	0.029
OU5 C-Ponds	12.760	0.098	0.003	0.029	0.029
OU5 Old Landfill	13.530	0.098	0.003	0.021	0.021
OU5 Surface Disturbance	1.660	NR	0.003	0.003	0.003
OU6 A-Ponds	12.830	0.098	0.003	0.020	0.020
OU6 B-Ponds	8.470	0.098	0.003	0.013	0.013
OU6 Burial Trenches	1.040	0.098	NR	0.002	0.002
OU6 North Spray Field	4.400	NR	0.003	0.007	0.007
OU6 Soil Dump Areas	18.040	0.098	0.003	0.028	0.028
OU7 Downgradient Areas	2.760	0.098	0.003	0.004	0.004
OU10 Outside Closures	2.690	NR	NR	0.004	0.004
OU11 West Spray Field	45.950	NR	0.003	0.071	0.071

¹ Soil ingestion rates from Attachment 1, Table 3
NR - no data are available for this media

Red-tailed Hawk Information

Environmental media for which intakes were calculated: small mammals and soil

Percent of diet represented: small mammals - 100% (DOE 1995b)

Assumes raptors do not drink surface water; all water needs are met through metabolism of prey

Total food ingestion rate: 0.098 kg/kg/day (DOE 1995b)

Home range: 650 ha (DOE 1995b)

Site Use Factors for food and soil intakes were calculated as: (area of source area) / (area of home range)

Table N3-17
Sources of Uncertainty and their Potential Effects on Exposure Estimations and Derivation of Toxicity Reference Values

Source	Effect	Remark
11 Assume mallard and great blue heron occur only in source areas with surface water samples	May over- or underestimate sitewide exposure to contaminants for mallard and great blue heron	Unsampled streams are ephemeral and in most cases do not possess significant aquatic attributes necessary to support great blue herons and/or mallards. Although mallards use other habitats, in summer they are found primarily near open water.
12 Assume summer diet for mallard	May over- or underestimate ingestion rates and probability of exceeding critical value	Mallards were chosen to represent aquatic feeding avian species; therefore, their summer diet is most appropriate for the exposure analysis. Also, mallards are most frequently observed at RFETS during the summer.
13 Assume terrestrial-feeding receptors ingest surface water from pond margins and streambanks, whereas aquatic-feeding receptors ingest water from total surface area of ponds/streams	May over- or underestimate ingestion rates and probability of exceeding critical value	Terrestrial species usually have access to water from pond and stream edges, whereas aquatic feeders such as herons and ducks have a larger surface area of water available to them.
14 Assume Preble's meadow jumping mouse, mallard, and great blue heron are only key receptors that ingest sediments	May over- or underestimate ingestion rates and probability of exceeding critical value	Most terrestrial receptors have minimal contact with sediments; however, mallards and great blue herons forage among sediments. Preble's meadow jumping mice may also be in more frequent contact with sediments.
15 Assume Preble's meadow jumping mouse and mallard ingest equal amounts of soil and sediments	May over- or underestimate ingestion rates and probability of exceeding critical value	Preble's meadow jumping mice and mallards spend significant amounts of time in contact with both soil and sediments.
16 Assume great blue heron does not ingest soil	May overestimate exposure to great blue herons from contaminants in sediments or underestimate exposure to great blue herons from contaminants in soil	Great blue herons spend minimal time on dry land and, therefore, have little direct contact with surface soils.
17 Assume that raptors do not ingest water	May underestimate ingestion of contaminants in surface water	Raptors obtain most of their water from moisture in prey through oxidative metabolism. Most raptors can survive without drinking, although they may occasionally drink negligible amounts ^{1,2} .
18 Assume small mammals represent 100% of American Kestrel diet except where data for contaminant concentrations in terrestrial arthropods exist	May over- or underestimate ingestion rates and probability of exceeding critical value	Minimal data for contaminant concentrations in terrestrial arthropods exist. Data for contaminant concentrations in bird tissues were too sparse to be of use.

Table N3-17
Sources of Uncertainty and their Potential Effects on Exposure Estimations and Derivation of Toxicity Reference Values

Source	Effect	Remark
19. Assume vegetation represents 100% of diet for Preble's meadow jumping mouse, coyote, mallard where data for other dietary components are not available	May over- or underestimate ingestion rates and probability of exceeding critical value	Contaminant concentrations in vegetation are conservatively estimated from subsurface soil contaminant concentrations
Toxicity Assessment		
20. Contaminant identification process a. All detected organics are considered PCOCs b. "Gilbert Toolbox" used to determine metals PCOCs	May overestimate number of site PCOCs	Both a and b are very conservative approaches.
21. Tissue analytes identified before contaminants known	Data on chemicals concentration in biological tissue not available for some PCOCs	BCFs and transfer coefficients from the literature were used in modeling uptake of some PCOCs.
22. Lack of specific toxicity information for exposure of Rocky Flats species to PCOCs	May over- or underestimate critical effects concentrations	Scaling factors were used to extrapolate literature-based toxicity information to Rocky Flats species. Also, see item 2.
23. Use most sensitive species in literature to set NOAEL	May over- or underestimate critical effects concentrations	Data for most sensitive species used to protect greater number of species.
24. Estimation of TRV from NOAEL and background data	May over- or underestimate critical effects concentrations	Results in protective values when combined with item 2.

¹Bartholomew and Cade, 1957, 1963

²Duke *et al.* 1973

BCF - bioconcentration factor
B-factor - transfer coefficient

**Table N3-18
Data Usability Categories**

Category	Definition	Validation Codes¹	Laboratory Qualifiers²
Valid	Fully usable	A, V	blank, U
Estimate	Usable as estimated result	A, J, V, JA ³	+, *, B, C, D, E (inorganics), F, G, H, I, J, N, S, UJ, UN, UW, UX, W, X, Y, Z
Reject	Not valid	B, C, N, P, R, S.	E (organics), L, R, UE (radionuclides)
Blank/Y Val	Acceptable or estimated result, no validation code	Y, blank	blank, +, *, B, C, D, E (inorganics), F, G, H, I, J, N, S, U, UJ, UN, UW, UX, W, X, Y, Z

¹ Data validation codes are defined in Attachment 3, Table 1.

² Laboratory qualifiers are defined in Attachment 3, Table 2.

³ If the validation code is J or JA, then U and blank laboratory qualifiers are considered to be estimates.

Table N3-19
Results of Ecological Contaminants of Concern Tier 3 Evaluation
Number of Analytes with HQ>1 for Source Areas with HI>1

Receptor	ERA Source Areas																	
	OU6 A-Ponds	OU6 B-Ponds	OU7 Downgradient	OU6 Soil Dump	OU6 Burial Trenches	OU5 Old Landfill	OU6 North Spray Fields	OU5 Ash Pits	OU2 903 Pad	OU2 East Trenches	OU1 881 Hillside	OU2 Mound Area	OU5 C-Ponds	OU4 Downgradient	OU11 West Spray Field	OU5 Surface Disturbance	OU10 Other Outside Closures	
Number of Analytes with HQ≥1																		
Wildlife Receptors																		
Preble's Meadow Jumping Mouse	3	3	2	2	2	2	3	2	1	2	1	HI<1	1	3	HI<1			
American Kestrel	5	6	0	3	0	0	HI<1	0	1	4	0	1	0	1	0	HI<1		
Great Blue Heron	3	4				5		1	1	HI<1	2		5					
Mallard	1	0							HI<1		HI<1		0					
Aquatic Species																		
Aquatic Organisms - Surface Water	2	2	3			1		1	3		2		2					
Vegetation Communities																		
Vegetation - Subsurface Soil	2		4	4	3	3	4	9	1	0	4	3	3	6	3			
Vegetation - Sediments	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Radiological Contaminants																		
Small Mammals - Surface Soils	HI<1	HI<1	HI<1	HI<1	HI<1	2	HI<1	HI<1	1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	
Aquatic Organisms - Sediments	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	
Aquatic Organisms - Surface Water	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	HI<1	
Aquatic Organisms - Sediments	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	

Receptor	ERA Source Areas														
	Pond A-1	Pond A-2	Pond A-3	Pond A-4	Pond A-5	Pond B-1	Pond B-2	Pond B-3	Pond B-4	Pond B-5	North Walnut Creek	South Walnut Creek	Pond C-1	Pond C-2	Woman Creek
Number of Analytes with HQ>1															
Wildlife Receptors															
Preble's Meadow Jumping Mouse	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
American Kestrel	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Great Blue Heron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mallard	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aquatic Species															
Aquatic Organisms - Surface Water	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vegetation Communities															
Vegetation - Subsurface Soil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vegetation - Sediments	4	3	4	4	3	4	4	5	5	3	3	HI<1	2	2	1
Radiological Contaminants															
Small Mammals - Surface Soils	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aquatic Organisms - Sediments	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aquatic Organisms - Surface Water	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aquatic Organisms - Sediments	10	8	7	4	5	17	18	11	12	3	11	12	1	2	0

Shading indicates that risk was not assessed for that receptor/source area combination
 NA - Not applicable

Table N3-20
Results of Ecological Contaminants of Concern Tier 3 Evaluation

ERA Source Areas													
Receptor/Analyte	OU1 881 Hillside	OU5 Ash Pits	OU5 C-Ponds	OU5 Old Landfill	OU2 903 Pad	OU2 East Trenches	OU4 Downgradient	OU6 A-Ponds	OU6 B-Ponds	OU2 Mound Area	OU6 North Spray Field	OU6 Burial Trenches	OU7 Downgradient
Wildlife Receptors													
Preble's Meadow Jumping Mouse													
Barium											X		
Selenium													X
American Kestrel													
Chromium					X	X		X		X			
Lead								X	X				
Mercury							X						X
Vanadium									X				
Great Blue Heron													
Antimony				X									
Aroclor-1254					X								
Di-N-butyl phthalate								X	X				
Mercury			X	X					X				
PCBs ¹													
Mallard													
Di-N-butyl phthalate								X					
PCBs ¹													
Aquatic Species													
Surface Water													
Barium	X	X	X										
Vegetation-Subsurface Soil													
Antimony	X												
Cadmium	X												
Chromium	X	X									X		
Copper	X			X									
Lead	X						X						
Nickel	X												
Nitrate/Nitrite							X						X
Silver	X												
Strontium												X	X
Zinc	X	X	X	X	X		X	X		X	X	X	X
Small Mammals													
Surficial Soils													
Plutonium-239/240													Sitewide Maximum
Uranium-233/234													Sitewide Maximum
Uranium-238													Sitewide Maximum

¹PCBs - polychlorinated biphenyls, included in the risk characterization due to its potential to bioaccumulate
X indicates that analyte is an ECOC in the specified source area

Table N3-21
List of PCOCs with HQs ≥ 1 Not Evaluated as ECOCs in the Risk Characterization

Receptor	Source Area	PCOC	HQ	Reason
Preble's Meadow Jumping Mouse	OU1 881 Hillside	Acetone	1.24	Not a PCOC in OU1
		Aluminum	1.10	Not a PCOC in OU5
	OU5 Ash Pits	Magnesium	1.02	Not a PCOC in OU5
		Cadmium	1.06	Not a PCOC in OU5
	OU5 C-Ponds	Magnesium	1.69	Not a PCOC in OU5
	OU5 Old Landfill	Aluminum	1.10	Not a PCOC in OU5
		Aluminum	1.10	Not a PCOC in OU2
	OU2 903 Pad	Copper	3.18	Not a PCOC in OU2
	OU2 East Trenches	Cadmium	1.75	Not a PCOC in OU2
		Selenium	1.95	Not a PCOC in OU4
	OU4 Downgradient	Magnesium	1.39	Not a PCOC in OU4
		Aluminum	1.20	Not a PCOC in OU4
	OU6 A-Ponds	Magnesium	1.55	Essential nutrient
		Selenium	1.35	Not a PCOC in OU6
		Aluminum	1.06	Not a PCOC in OU6
	OU6 B-Ponds	Selenium	1.52	Not a PCOC in OU6
		Magnesium	1.17	Essential nutrient
		Aluminum	1.12	Not a PCOC in OU6
	OU6 North Spray Field	Magnesium	2.86	Essential nutrient
		Aluminum	1.33	Not a PCOC in OU6
	OU6 Burial Trenches	Selenium	1.38	Not a PCOC in OU6
		Magnesium	1.05	Essential nutrient
American Kestrel	OU2 East Trenches	Magnesium	1.69	Essential nutrient
		Selenium	3.55	Not a PCOC in OU6
		Magnesium	1.06	Essential nutrient
	OU6 A-Ponds	Copper	12.00	Not a PCOC in OU2
		Zinc	2.81	Not a PCOC in OU2
		Lithium	1.07	Not a PCOC in OU2
		Magnesium	3.32	Essential Nutrient
	OU6 B-Ponds	Zinc	1.41	Essential Nutrient
		Vanadium	1.15	Only 1/3 hits had conc. above det. limit
		Selenium	3.97	Not a PCOC in OU6
		Magnesium	2.86	Essential nutrient
		Aluminum	1.17	Not a PCOC in OU6
Great Blue Heron	OU6 Soil Dump	Mercury	1.00	Only 2/9 hits had conc. above det. limit
		Beryllium	3.07	Not a PCOC in OU6
		Magnesium	1.53	Essential nutrient
	OU1 881 Hillside	Magnesium	1.95	Not a PCOC in OU1
		Aluminum	1.43	Not a PCOC in OU1
	OU5 Old Landfill	Cadmium	3.26	Not a PCOC in OU5
		Magnesium	1.63	Not a PCOC in OU5
		Aluminum	1.44	Not a PCOC in OU5
	OU5 Ash Pits	Cadmium	2.98	Not a PCOC in OU5
	OU5 C-Ponds	Selenium	2.64	Not a PCOC in OU5
		Aluminum	1.19	Not a PCOC in OU5
		Copper	1.14	Does not bioaccumulate, and more realistic assumptions about seasonal exposure factors would result in negligible risk.
		Magnesium	1.10	
	OU6 A-Ponds	Magnesium	1.39	Essential nutrient
		Aluminum	1.26	Not a PCOC in OU6
	OU6 B-Ponds	Magnesium	1.28	Essential nutrient
		Aluminum	1.04	Not a PCOC in OU6

Table N3-21
List of PCOCs with HQs ≥ 1 Not Evaluated as ECOCs in the Risk Characterization

Receptor	Source Area	PCOC	HQ	Reason
Vegetation Community	OU4 Downgradient	Lithium	3.7	Not a PCOC in OU4
		Strontium	1.1	Not a PCOC in OU4
		Vanadium	1.1	Not a PCOC in OU4
	OU6 A-Ponds	Lithium	6.6	Not a PCOC in OU6
	OU2 Mound Area	Antimony	1.6	Not a PCOC in OU2
		Strontium	1.5	Not a PCOC in OU2
	OU6 North Spray Field	Lithium	2.2	Not a PCOC in OU6
		Antimony	1.3	Not a PCOC in OU6
	OU11 West Spray Field	Lithium	2.7	Not a PCOC in OU11
		Chromium	2.1	Not a PCOC in OU11
		Mercury	1.6	Not a PCOC in OU11
	OU6 Burial Trenches	Lithium	2.4	Not a PCOC in OU6
		Antimony	1.0	Not a PCOC in OU6
	OU7 Downgradient Area	Lithium	4.0	Not a PCOC in OU7
	OU6 Soil Dump Areas	Lithium	3.9	Not a PCOC in OU6
		Antimony	1.2	Not a PCOC in OU6
	OU1 881 Hillside	Lithium	5.2	Not a PCOC in OU1
		Antimony	1.5	Not a PCOC in OU1
		Strontium	1.4	Not a PCOC in OU1
		Zinc	1.2	Not a PCOC in OU1
	OU5 Ash Pits	Lithium	4.9	Not a PCOC in OU5
	OU5 C-Ponds	Lithium	3.4	Not a PCOC in OU5
	OU5 Old Landfill	Lithium	3.6	Not a PCOC in OU5
Wetland Vegetation Community	Pond A-1	Aluminum	1.90	Not a PCOC in OU6
		Strontium	1.70	Not a PCOC in OU6
		Mercury	1.40	Not a PCOC in OU6
	Pond A-2	Strontium	1.80	Not a PCOC in OU6
		Aluminum	1.40	Not a PCOC in OU6
	Pond A-3	Aluminum	3.80	Not a PCOC in OU6
		Lithium	1.80	Not a PCOC in OU6
		Strontium	1.50	Not a PCOC in OU6
	Pond A-4	Aluminum	2.90	Not a PCOC in OU6
		Strontium	1.90	Not a PCOC in OU6
		Selenium	1.40	Not a PCOC in OU6
		Lithium	1.10	Not a PCOC in OU6
	Pond A-5	Aluminum	1.60	Not a PCOC in OU6
		Strontium	1.30	Not a PCOC in OU6
	Pond B-1	Mercury	3.30	Not a PCOC in OU6
		Lead	2.40	Not a PCOC in OU6
		Strontium	2.20	Not a PCOC in OU6
		Cadmium	2.20	Not a PCOC in OU6
		Aluminum	1.40	Not a PCOC in OU6
		Nickel	1.00	Not a PCOC in OU6
		Beryllium	1.00	Not a PCOC in OU6
	Pond B-2	Strontium	6.20	Not a PCOC in OU6
		Mercury	1.60	Not a PCOC in OU6
		Selenium	1.60	Not a PCOC in OU6
		Cadmium	1.50	Not a PCOC in OU6
		Aluminum	1.10	Not a PCOC in OU6
	Pond B-3	NA	N/A	Not a PCOC in OU6
	Pond B-4	Aluminum	1.90	Not a PCOC in OU6
		Strontium	1.80	Not a PCOC in OU6
	Pond B-5	Aluminum	2.80	Not a PCOC in OU6
		Strontium	1.40	Not a PCOC in OU6
		Lithium	1.30	Not a PCOC in OU6

Table N3-21
List of PCOCs with HQs \geq 1 Not Evaluated as ECOCs in the Risk Characterization

Receptor	Source Area	PCOC	HQ	Reason
Wetland Vegetation Community	North Walnut Creek	Antimony	2.90	Not a PCOC in OU6
		Aluminum	1.20	Not a PCOC in OU6
	South Walnut Creek	NA	N/A	
	Woman Creek	Antimony	1.50	Not a PCOC in OU5
		Aluminum	1.40	Not a PCOC in OU5
		Selenium	1.20	Not a PCOC in OU5
		Vanadium	1.20	Not a PCOC in OU5
		Chromium	1.00	Not a PCOC in OU5
	Pond C-1	Aluminum	2.20	Not a PCOC in OU5
		Chromium	2.00	Not a PCOC in OU5
		Lithium	1.80	Not a PCOC in OU5
		Vanadium	1.70	Not a PCOC in OU5
		Selenium	1.50	Not a PCOC in OU5
		Strontium	1.50	Not a PCOC in OU5
	Pond C-2	Strontium	3.30	Not a PCOC in OU5
		Vanadium	1.90	Not a PCOC in OU5
		Chromium	1.80	Not a PCOC in OU5
		Aluminum	1.80	Not a PCOC in OU5
		Lithium	1.10	Not a PCOC in OU5

Table N3-22
Sediment PCOCs with Exposure Point HQs >1 by Pond

Analyte	Group	Pond A-1	Pond A-2	Pond A-3	Pond A-4	Pond A-5	Pond B-1	Pond B-2	Pond B-3	Pond B-4	Pond B-5	North Walnut Creek	South Walnut Creek	Pond C-1	Pond C-2	Woman Creek
Aquatic Life																
Antimony	M	X		X	X				X	X						
Arsenic	M											X	X			
Barium	M															
Chromium	M															
Cobalt	M	X	X	X					X	X						
Copper	M															
Magnesium	M	X	X	X					X	X						
Manganese	M								X	X						
Silver	M															
Strontium	M															
Vanadium	M	X	X	X	X				X	X						
Zinc	M		X	X					X	X					X	
Aldrin	P		X													
Aroclor-1254 ¹	P	X							X	X						
Aroclor-1260 ¹	P								X	X						
gamma-BHC (Lindane)	P															
Heptachlor	P															
Anthracene ²	S	X								X	X					
Benzo(b)fluoranthene ²	S	X								X	X					
Benzo(g,h,i)perylene ²	S															
Benzo(k)fluoranthene ²	S	X														
Chrysene ²	S	X	X	X					X	X						
Dibenzo(a,h)anthracene ²	S															
Fluorene ²	S															
Naphthalene ²	S															
Benzoic acid	S		X													
Acetone	V		X												X	
Methylene chloride	V															
Toluene	V	X														
Wetland Vegetation Communities																
Antimony	M	X		X	X				X	X						
Chromium	M	X	X	X					X	X						
Mercury	M													X	X	
Silver	M								X	X						
Strontium	M															
Vanadium	M	X	X	X	X				X	X						
Zinc	M	X	X	X	X				X	X				X	X	X

¹Polychlorinated biphenyls (PCBs)
²Polycyclic aromatic hydrocarbons (PAHs)

Table N3-23
Vegetation ECOCs Subsurface Soil and Sediments

Source Area	Subsurface Soil ECOCs	Subsurface Soil Hazard Quotient	Sediment ECOCs	Sediment Hazard Quotient
Walnut Creek Watershed				
OU2 903 Pad	Zinc	1.2		
OU2 Mound Area	Zinc	1.4		
OU4 Downgradient	Nitrate/Nitrite	4.8		
	Zinc	1.4		
	Lead	1.3		
OU6 A-Ponds	Zinc	1.0		
Pond A-1			Antimony	3.8
			Chromium	1.9
			Vanadium	1.7
			Zinc	1.5
Pond A-2			Zinc	3.9
			Vanadium	1.4
			Chromium	1.0
Pond A-3			Antimony	3.0
			Chromium	2.8
			Vanadium	2.8
			Zinc	2.1
Pond A-4			Antimony	5.2
			Vanadium	2.4
			Zinc	1.9
			Chromium	1.6
Pond A-5			Vanadium	1.6
			Chromium	1.3
			Zinc	1.0
OU6 B-Ponds				
Pond B-1			Silver	88
			Zinc	10
			Chromium	6.6
			Vanadium	1.4
Pond B-2			Silver	51
			Chromium	2.0
			Zinc	1.7
			Vanadium	1.1
Pond B-3			Silver	63
			Antimony	8.9
			Zinc	3.3
			Chromium	2.9
			Vanadium	1.4
Pond B-4			Silver	15
			Zinc	3.5
			Antimony	3.3
			Vanadium	1.8
			Chromium	1.8

**Table N3-23
Vegetation ECOCs Subsurface Soil and Sediments**

Source Area	Subsurface Soil ECOCs	Subsurface Soil Hazard Quotient	Sediment ECOCs	Sediment Hazard Quotient
Pond B-5			Vanadium	2.2
			Zinc	2.0
			Chromium	2.0
North Walnut Creek			Zinc	1.3
			Vanadium	1.3
			Strontium	1.1
South Walnut Creek			NA	NA
OU6 Burial Trenches	Strontium	1.5		
OU6 Soil Dump Areas	Strontium	1.6		
	Zinc	1.0		
OU6 North Spray Field	Chromium	1.2		
	Zinc	1.0		
OU7 Downgradient Areas	Nitrate/Nitrite	170		
	Strontium	1.6		
	Zinc	1.5		
Woman Creek Watershed				
OU5 Ash Pits	Chromium	7.9		
	Nickel	3.7		
	Zinc	3.0		
	Silver	2.0		
	Antimony	1.3		
	Lead	1.1		
	Copper	1.1		
	Cadmium	1.0		
OU5 Old Landfill	Copper	2.6		
	Zinc	2.0		
OU5 C-Ponds	Chromium	2.7		
	Zinc	1.1		
Pond C-1			Mercury	6.0
			Zinc	1.5
Pond C-2			Zinc	2.8
			Mercury	2.3
Woman Creek			Zinc	1.6
OU2 903 Pad	Zinc	1.2		

OU - operable unit

ECOC - ecological chemical of concern

In the following source areas, all PCOCs had HQs less than one:

OU1 881 Hillside

OU11 West Spray Field

OU2 East Trenches

Table N3-24
Summary of Risk Estimates by Receptor

Receptors at Risk	Source Areas	Exposure Points		HQ
		Contributing the Most Risk	ECOC	
Aquatic Species	North Walnut Creek	Sediments	Anthracene	110
			Barium	1.4
			Benzo(b)fluoranthene	15
			Benzoic acid	8.2
			Chrysene	32
			Cobalt	1.4
			Magnesium	1.6
			Manganese	1.2
			Methylene chloride	9.5
			Strontium	1.1
	South Walnut Creek	Sediments	Vanadium	1.2
			Anthracene	140
			Barium	1.3
			Benzo(b)fluoranthene	19
			Benzo(k)fluoranthene	1.5
			Benzoic acid	1.3
			Chrysene	38
			Cobalt	1.0
			Magnesium	1.3
			Methylene chloride	17
	OU2 903 Pad Pond A-1	Surface Water Sediments	Naphthalene	1,100
			Strontium	1.3
			Vanadium	1.3
			Zinc	1.8
			Barium	39
			Anthracene	88
			Antimony	3.7
			Aroclor-1254	1.3
			Benzo(b)fluoranthene	18
			Benzo(k)fluoranthene	1.2
	Pond A-2	Sediments	Chrysene	34
			Cobalt	1.8
			Magnesium	2.4
			Toluene	2.2
			Vanadium	1.7
			Acetone	1.5
			Aldrin	35,000
			Benzoic acid	1.7
			Chrysene	3.9
			Cobalt	1.5
	Pond A-3	Sediments	Magnesium	2.3
			Vanadium	1.4
			Zinc	1.9
			Antimony	3.0
			Benzo(b)fluoranthene	18
			Chrysene	29
			Cobalt	2.1
			Magnesium	3.0
			Vanadium	2.8
			Zinc	1.0

Table N3-24
Summary of Risk Estimates by Receptor

Receptors at Risk	Source Areas	Exposure Points		HQ
		Contributing the Most Risk:	ECOC	
Aquatic Species (continued)	Pond A-4	Sediments	Antimony	5.2
			Cobalt	2.0
			Magnesium	2.6
			Vanadium	2.3
	Pond A-5	Sediments	Acetone	2.9
			Benzoic acid	7.7
			Cobalt	1.8
			Magnesium	1.7
	Pond B-1	Sediments	Vanadium	1.6
			Acetone	2.2
			Anthracene	270
			Aroclor-1254	8.9
			Benzo(b)fluoranthene	61
			Benzo(k)fluoranthene	2.8
			Chrysene	94
			Cobalt	1.6
			Copper	2.6
			Dibenzo(ah)anthracene	1.4
			Fluorene	1,400
			Heptachlor	230
			Magnesium	2.0
			Methylene chloride	4.3
			Naphthalene	3,500
			Silver	90
			Vanadium	1.4
			Zinc	4.8
	Pond B-2	Sediments	Acetone	3.1
			Aroclor-1254	4.3
			Chrysene	7.7
			Cobalt	1.7
			Magnesium	3.1
			Manganese	1.2
			Silver	52
			Vanadium	1.1
	Pond B-3	Sediments	Antimony	8.9
			Aroclor-1254	4.0
			Aroclor-1260	48
			Benzo(b)fluoranthene	18
			Chrysene	32
			Cobalt	1.7
			Copper	1.9
			Magnesium	1.8
			Silver	64
			Vanadium	1.4
			Zinc	1.6

Table N3-24
Summary of Risk Estimates by Receptor

Receptors at Risk	Source Areas	Exposure Points		HQ
		Contributing the Most Risk	ECOC	
Aquatic Species (continued)	Pond B-4	Sediments	Anthracene	110
			Antimony	3.3
			Aroclor-1254	1.7
			Benzo(b)fluoranthene	51
			Benzo(k)fluoranthene	2.1
			Chrysene	62
			Cobalt	1.5
			gamma-BHC (Lindane)	12
			Magnesium	2.3
			Silver	15
			Vanadium	1.8
			Zinc	1.7
	Pond B-5	Sediments	Cobalt	1.6
			Magnesium	2.5
			Vanadium	2.1
	OU7 Downgradient	Surface Water	Barium	45
			Barium	45
			Manganese	2.4
			Strontium	1.5
	OU5 Ash Pits	Surface Water	Barium	17.00
	OU5 C-Ponds	Surface Water	Barium	24
	Pond C-1	Sediments	Benzoic acid	2.6
	Pond C-2	Sediments	Benzoic acid	1.7
			Zinc	1.3
	OU5 Old Landfill	Surface Water	Barium	37
Preble's Meadow Jumping Mouse	OU6 North Spray Fields	Vegetation	Barium	1.05
	OU7 Downgradient	Vegetation	Selenium	2.36
Small Mammals	OU2 903 Pad	Sediments	Toluene	1,900
			Plutonium-239/240	1.92
	OU2 East Trenches	Subsurface Soil	Toluene	20
	OU5 Old Landfill	Surface Soils	Uranium-233/234	1.56
			Uranium-238	23.8
American Kestrel	OU2 903 Pad	Terrestrial Arthropods	Chromium	5.56
	OU2 East Trenches	Terrestrial Arthropods	Chromium	4.36
	OU4 Downgradient	Small Mammals	Mercury	1.36
	OU6 A-Ponds	Small Mammals	Lead	1.76
			Chromium	1.33
	OU6 B-Ponds	Small Mammals	Lead	1.25
			Vanadium	2.86
	OU2 Mound Area	Terrestrial Arthropods	Chromium	2.53
	OU6 Soil Dump Area	Small Mammals	Mercury	3.14
Great Blue Heron	OU2 903 Pad	Fish	Aroclor-1254	5.78
	OU6 A-Ponds	Fish	Di-N-butyl phthalate	16.56
	A-Ponds	Sediments	PCBs	NA
	OU6 B-Ponds	Fish	Mercury	2.40
			Di-N-butyl phthalate	8.27
	B-Ponds	Sediments	PAHs	NA
			PCBs	NA
	OU5 C-Ponds	Fish	Mercury	6.40
	OU5 Old Landfill	Fish	Mercury	28.8
	OU5 Old Landfill	Sediments	Antimony	1.56

Table N3-24
Summary of Risk Estimates by Receptor

Receptors at Risk	Source Areas	Exposure Points		ECOC	HQ
		Contributing the Most Risk			
Mallard	OU6 A-Ponds	Benthic Macroinvertebrates	Di-N-butyl phthalate	2.00	
	A-Ponds	Sediments	PCBs	NA	
	B-Ponds	Sediments	PCBs	NA	
Vegetation Communities	OU2 903 Pad	Subsurface Soil	Zinc	1.2	
	OU4 Downgradient	Subsurface Soil	Nitrate/Nitrite	4.8	
			Zinc	1.4	
			Lead	1.3	
	OU6 A-Ponds	Subsurface Soil	Zinc	1.0	
	OU2 Mound Area	Subsurface Soil	Zinc	1.4	
	OU6 North Spray Fields	Subsurface Soil	Chromium	1.2	
			Zinc	1.0	
	OU6 Burial Trenches	Subsurface Soil	Strontium	1.5	
	OU7 Downgradient	Subsurface Soil	Nitrate/Nitrite	170	
			Strontium	1.6	
			Zinc	1.5	
	OU6 Soil Dump Area	Subsurface Soil	Strontium	1.6	
			Zinc	1.0	
	OU5 Ash Pits	Subsurface Soil	Chromium	7.9	
			Nickel	3.7	
			Zinc	3.0	
			Silver	2.0	
			Antimony	1.3	
			Copper	1.1	
			Lead	1.1	
			Cadmium	1.0	
	OU5 C-Ponds	Subsurface Soil	Chromium	2.7	
			Zinc	1.1	
	OU5 Old Landfill	Subsurface Soil	Copper	2.6	
			Zinc	2.0	
Wetland Vegetation Communities	North Walnut Creek	Sediments	Zinc	1.3	
			Vanadium	1.3	
			Strontium	1.1	
	Pond A-1	Sediments	Antimony	3.8	
			Chromium	1.9	
			Vanadium	1.7	
			Zinc	1.5	
	Pond A-2	Sediments	Zinc	3.9	
			Vanadium	1.4	
			Chromium	1.0	
	Pond A-3	Sediments	Antimony	3.0	
			Chromium	2.8	
			Vanadium	2.8	
			Zinc	2.1	
	Pond A-4	Sediments	Antimony	5.2	
			Vanadium	2.4	
			Zinc	1.9	
			Chromium	1.6	
	Pond A-5	Sediments	Vanadium	1.6	
			Chromium	1.3	
			Zinc	1.0	

Table N3-24
Summary of Risk Estimates by Receptor

Receptors at Risk	Source Areas	Exposure Points		HQ
		Contributing the Most Risk	ECOC	
	Pond B-1	Sediments	Silver	88.0
			Zinc	10.0
			Chromium	6.6
			Vanadium	1.4
	Pond B-2	Sediments	Silver	51.0
			Chromium	2.0
			Zinc	1.7
			Vanadium	1.1
	Pond B-3	Sediments	Silver	63.0
			Antimony	8.9
			Zinc	3.3
			Chromium	2.9
			Vanadium	1.4
	Pond B-4	Sediments	Silver	15.0
			Zinc	3.5
			Antimony	3.3
			Vanadium	1.8
			Chromium	1.8
	Pond B-5	Sediments	Vanadium	2.2
			Zinc	2.0
			Chromium	2.0
	Woman Creek	Sediments	Zinc	1.6
	Pond C-1	Sediments	Mercury	6.0
			Zinc	1.5
	Pond C-2	Sediments	Zinc	2.8
	Pond C-2	Subsurface Soil	Mercury	2.3

¹Radionuclide benchmarks use small mammals as the limiting species, but Preble's meadow jumping mouse can be substituted, because it represents our small mammal receptor.

Two significant figures were presented for all receptors except wildlife receptors.

Table N3-25
Summary of Risk Estimates for ECOCs by Source Area

Source Areas	Receptors at Risk	Exposure Points Contributing the Most Risk	ECOC	HQ
Walnut Creek Watershed				
North Walnut Creek	Aquatic Species	Sediments	Anthracene	110
			Chrysene	32
			Benzo(b)fluoranthene	15
			Methylene chloride	9.5
			Benzoic acid	8.2
			Magnesium	1.6
			Barium	1.4
			Cobalt	1.4
			Vanadium	1.2
			Manganese	1.2
			Strontium	1.1
	Wetland Vegetation Communities	Sediments	Zinc	1.3
			Vanadium	1.3
			Strontium	1.1
South Walnut Creek	Aquatic Species	Sediments	Naphthalene	1,100
			Anthracene	140
			Chrysene	38
			Benzo(b)fluoranthene	19
			Methylene chloride	17
			Zinc	1.8
			Benzo(k)fluoranthene	1.5
			Magnesium	1.3
			Benzoic acid	1.3
			Vanadium	1.3
			Barium	1.3
			Strontium	1.3
			Cobalt	1.0
OU2 903 Pad	American Kestrel	Terrestrial Arthropods	Chromium	5.56
	Aquatic Species	Surface Water	Barium	39
	Great Blue Heron	Fish	Aroclor-1254	5.78
	Small Mammals	Sediments	Toluene	1,900
	Small Mammals ¹	Surface Soils	Plutonium-239/240	1.92
	Vegetation Communities	Subsurface Soil	Zinc	1.2
OU2 East Trenches	American Kestrel	Terrestrial Arthropods	Chromium	4.36
	Small Mammals	Subsurface Soil	Toluene	20.0
OU2 Mound Area	American Kestrel	Terrestrial Arthropods	Chromium	2.53
	Vegetation Communities	Subsurface Soil	Zinc	1.4
OU4 Downgradient	American Kestrel	Small Mammals	Mercury	1.36
	Vegetation Communities	Subsurface Soil	Nitrate/Nitrite	4.8
			Zinc	1.4
			Lead	1.3
OU6 A-Ponds	American Kestrel	Small Mammals	Lead	1.76
			Chromium	1.33
	Great Blue Heron	Fish	Di-N-butyl phthalate	16.56
	Mallard	Benthic Macroinvertebrates	Di-N-butyl phthalate	2.00
	Vegetation Communities	Subsurface Soil	Zinc	1.0
	Great Blue Heron	Sediments	PCBs	NA
	Mallard	Sediments	PCBs	NA

Table N3-25
Summary of Risk Estimates for ECOCs by Source Area

Source Areas	Receptors at Risk	Exposure Points		HQ
		Contributing the Most Risk	ECOC	
Pond A-1	Aquatic Species	Sediments	Anthracene	88
			Chrysene	34
			Benzo(b)fluoranthene	18
			Antimony	3.7
			Magnesium	2.4
			Toluene	2.2
			Cobalt	1.8
			Vanadium	1.7
			Aroclor-1254	1.3
			Benzo(k)fluoranthene	1.2
	Wetland Vegetation Communities	Sediments	Antimony	3.8
			Chromium	1.9
			Vanadium	1.7
			Zinc	1.5
Pond A-2	Aquatic Species	Sediments	Aldrin	35,000
			Chrysene	3.9
			Magnesium	2.3
			Zinc	1.9
			Benzoic acid	1.7
			Acetone	1.5
			Cobalt	1.5
	Wetland Vegetation Communities	Sediments	Vanadium	1.4
			Zinc	3.9
			Vanadium	1.4
			Chromium	1.0
Pond A-3	Aquatic Species	Sediments	Chrysene	29
			Benzo(b)fluoranthene	18
			Antimony	3.0
			Magnesium	3.0
			Vanadium	2.8
			Cobalt	2.1
			Zinc	1.0
	Wetland Vegetation Communities	Sediments	Antimony	3.0
			Chromium	2.8
			Vanadium	2.8
			Zinc	2.1
Pond A-4	Aquatic Species	Sediments	Antimony	5.2
			Magnesium	2.6
			Vanadium	2.3
			Cobalt	2.0
	Wetland Vegetation Communities	Sediments	Antimony	5.2
			Vanadium	2.4
			Zinc	1.9
Pond A-5	Aquatic Species	Sediments	Chromium	1.6
			Benzoic acid	7.7
			Acetone	2.9
			Cobalt	1.8
			Magnesium	1.7
	Wetland Vegetation Communities	Sediments	Vanadium	1.6
			Vanadium	1.6
			Chromium	1.3
			Zinc	1.0

Table N3-25
Summary of Risk Estimates for ECOCs by Source Area

Source Areas	Receptors at Risk	Exposure Points Contributing the Most Risk	ECOC	HQ
OU6 B-Ponds	American Kestrel	Small Mammals	Lead	1.25
			Vanadium	2.86
	Great Blue Heron	Fish	Mercury	2.40
			Di-N-butyl phthalate	8.27
	Great Blue Heron	Sediments	PCBs	NA
Pond B-1	Mallard	Sediments	PCBs	NA
			PCBs	NA
	Aquatic Species	Sediments	Naphthalene	3.500
			Fluorene	1.400
			Anthracene	270
			Heptachlor	230
			Chrysene	94
			Silver	90
			Benzo(b)fluoranthene	61
			Aroclor-1254	8.9
			Zinc	4.8
			Methylene chloride	4.3
			Benzo(k)fluoranthene	2.8
			Copper	2.6
			Acetone	2.2
			Magnesium	2.0
			Cobalt	1.6
			Vanadium	1.4
			Dibenzo(ah)anthracene	1.4
	Wetland Vegetation Communities	Sediments	Silver	88.0
			Zinc	10.0
			Chromium	6.6
			Vanadium	1.4
Pond B-2	Aquatic Species	Sediments	Silver	52
			Chrysene	7.7
			Aroclor-1254	4.3
			Magnesium	3.1
			Acetone	3.1
			Cobalt	1.7
			Manganese	1.2
			Vanadium	1.1
	Wetland Vegetation Communities	Sediments	Silver	51.0
			Chromium	2.0
			Zinc	1.7
			Vanadium	1.1
Pond B-3	Aquatic Species	Sediments	Silver	64
			Aroclor-1260	48
			Chrysene	32
			Benzo(b)fluoranthene	18
			Antimony	8.9
			Aroclor-1254	4.0
			Copper	1.9
			Magnesium	1.8
			Cobalt	1.7
			Zinc	1.6
			Vanadium	1.4

Table N3-25
Summary of Risk Estimates for ECOCs by Source Area

Source Areas	Receptors at Risk	Exposure Points		ECOC	HQ
		Contributing the Most Risk			
Pond B-3	Wetland Vegetation Communities	Sediments	Silver	63.0	
			Antimony	8.9	
			Zinc	3.3	
			Chromium	2.9	
			Vanadium	1.4	
Pond B-4	Aquatic Species	Sediments	Anthracene	110	
			Chrysene	62	
			Benzo(b)fluoranthene	51	
			Silver	15	
			gamma-BHC (Lindane)	12	
			Antimony	3.3	
			Magnesium	2.3	
			Benzo(k)fluoranthene	2.1	
			Vanadium	1.8	
			Zinc	1.7	
			Aroclor-1254	1.7	
			Cobalt	1.5	
			Wetland Vegetation Communities	Sediments	Silver
	Zinc	3.5			
	Antimony	3.3			
	Vanadium	1.8			
	Chromium	1.8			
	Pond B-5	Aquatic Species	Sediments	Magnesium	2.5
Vanadium				2.1	
Cobalt				1.6	
Wetland Vegetation Communities		Sediments	Vanadium	2.2	
			Zinc	2.0	
			Chromium	2.0	
OU6 North Spray Fields	Preble's Meadow Jumping Mouse	Vegetation	Barium	1.05	
	Vegetation Communities	Subsurface Soil	Chromium	1.2	
			Zinc	1.0	
OU6 Burial Trenches	Vegetation Communities	Subsurface Soil	Strontium	1.5	
OU6 Soil Dump Area	American Kestrel	Small Mammals	Mercury	3.14	
	Vegetation Communities	Subsurface Soil	Strontium	1.6	
			Zinc	1.0	
OU7 Downgradient	Aquatic Species	Surface Water	Barium	45	
			Manganese	2.4	
			Strontium	1.5	
			Barium	45	
	Preble's Meadow Jumping Mouse	Vegetation	Selenium	2.36	
	Vegetation Communities	Subsurface Soil	Nitrate/Nitrite	170	
			Strontium	1.6	
			Zinc	1.5	

Table N3-25
Summary of Risk Estimates for ECOCs by Source Area

Source Areas	Receptors at Risk	Exposure Points Contributing the Most Risk	ECOC	HQ
Woman Creek Watershed				
Woman Creek	Wetland Vegetation Communities	Sediments	Zinc	1.6
OU5 Ash Pits	Aquatic Species	Surface Water	Barium	17.00
		Subsurface Soil	Chromium	7.9
	Vegetation Communities		Nickel	3.7
			Zinc	3.0
			Silver	2.0
			Antimony	1.3
			Copper	1.1
			Lead	1.1
			Cadmium	1.0
OU5 C-Ponds	Aquatic Species	Surface Water	Barium	24
	Great Blue Heron	Fish	Mercury	6.40
	Vegetation Communities	Subsurface Soil	Chromium	2.7
			Zinc	1.1
Pond C-1	Aquatic Species	Sediments	Benzoic acid	2.6
	Wetland Vegetation Communities	Sediments	Mercury	6.0
			Zinc	1.5
Pond C-2	Aquatic Species	Sediments	Benzoic acid	1.7
			Zinc	1.3
	Wetland Vegetation Communities	Sediments	Zinc	2.8
		Subsurface Soil	Mercury	2.3
OU5 Old Landfill	Aquatic Species	Surface Water	Barium	37
	Great Blue Heron	Fish	Mercury	28.8
		Sediments	Antimony	1.56
	Small Mammals ¹	Surface Soils	Uranium-233/234	1.56
			Uranium-238	23.8
	Vegetation Communities	Subsurface Soil	Copper	2.6
			Zinc	2.0
OU2 903 Pad	American Kestrel	Terrestrial Arthropods	Chromium	5.56
	Aquatic Species	Surface Water	Barium	39
	Great Blue Heron	Fish	Aroclor-1254	5.78
	Small Mammals	Sediments	Toluene	1,900
	Small Mammals ¹	Surface Soils	Plutonium-239/240	1.92
	Vegetation Communities	Subsurface Soil	Zinc	1.2
OU2 East Trenches	American Kestrel	Terrestrial Arthropods	Chromium	4.36
	Small Mammals	Subsurface Soil	Toluene	20

¹Radionuclide benchmarks use small mammals as the limiting species, but Preble's meadow jumping mouse can be substituted, because it represents our small mammal receptor.

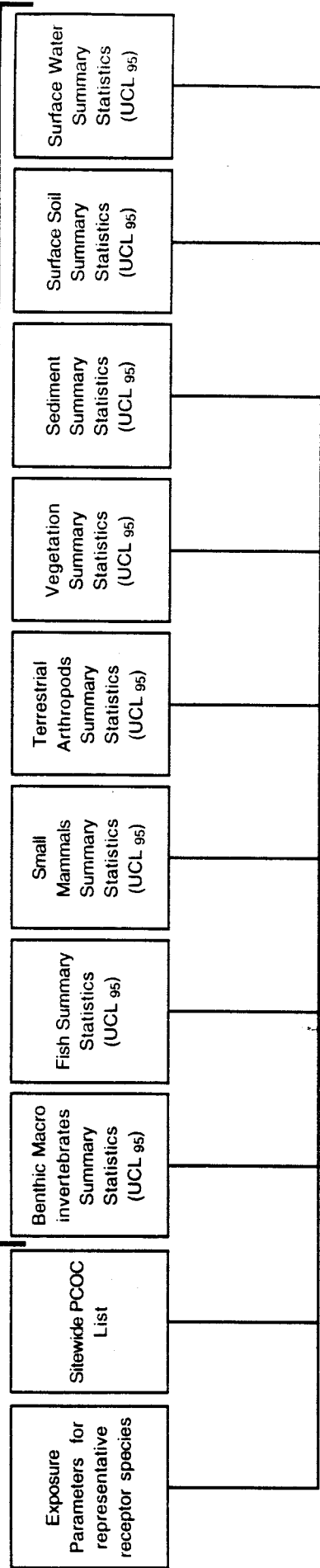
Two significant figures were presented for all receptors except wildlife receptors.

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CHAPTER N3

FIGURES

Data on PCOC concentrations in biotic and abiotic media



Estimate PCOC concentration in Benthic Macroinvertebrates and Fish using bioconcentration factors

Estimate PCOC Concentration in vegetation using K_{ow}

Estimated values for Vegetation, Benthic Macroinvertebrates, and Fish are used if a given analyte is not represented

Calculate PCOC Intakes for receptor species for each ERA source area

Wildlife Intake Database

Toxicity Reference Values (TRVs)

Literature-based Benchmarks

Background Intake

Hazard Quotient is calculated by dividing estimated intake by TRV

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

ERAs for Woman Creek and Walnut Creek
Watersheds at RFETS

**Conceptual Model for Use of Site
Data and Literature Information in
Exposure and Risk Estimates**

September 1995

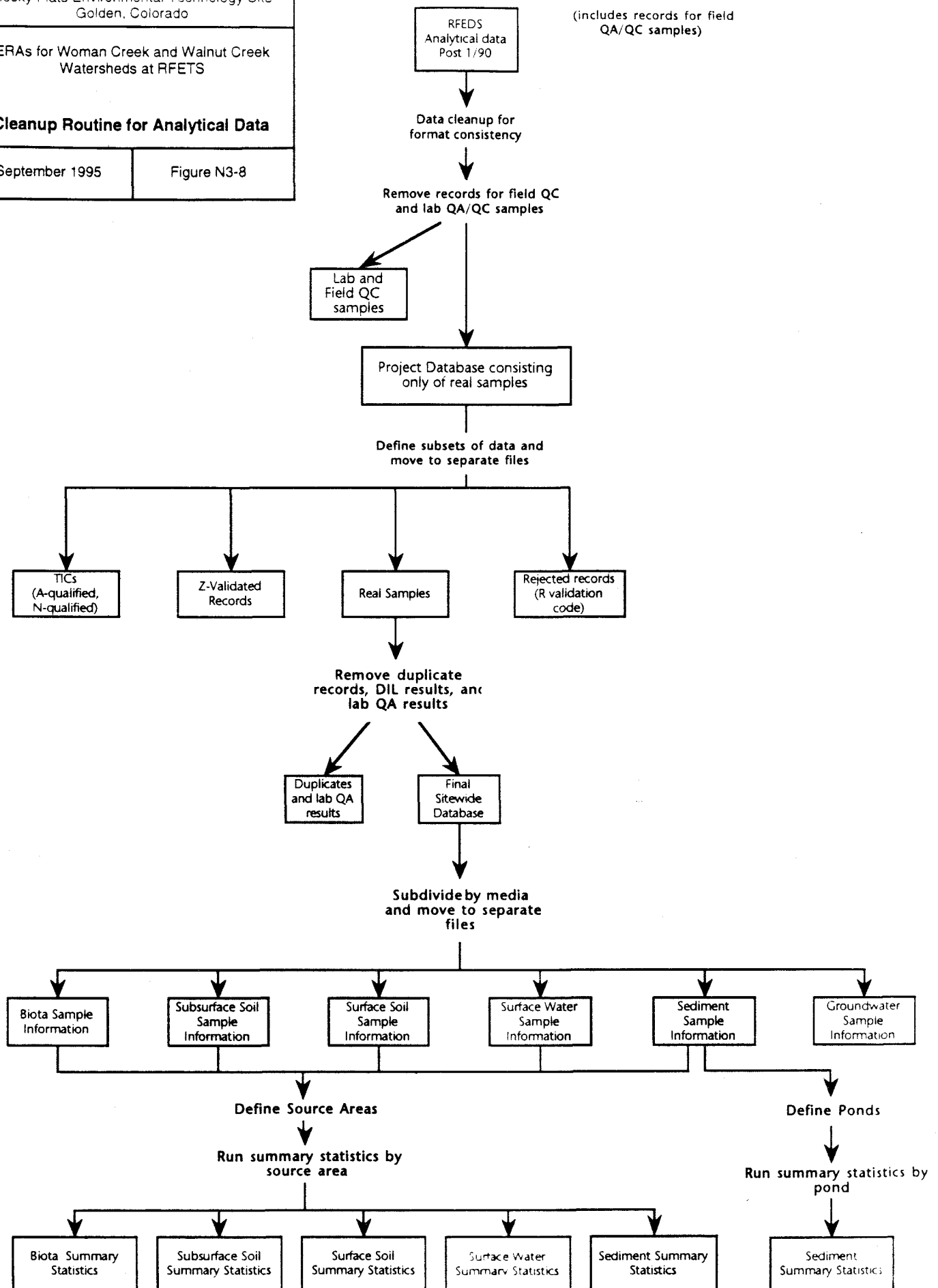
Figure N3-4

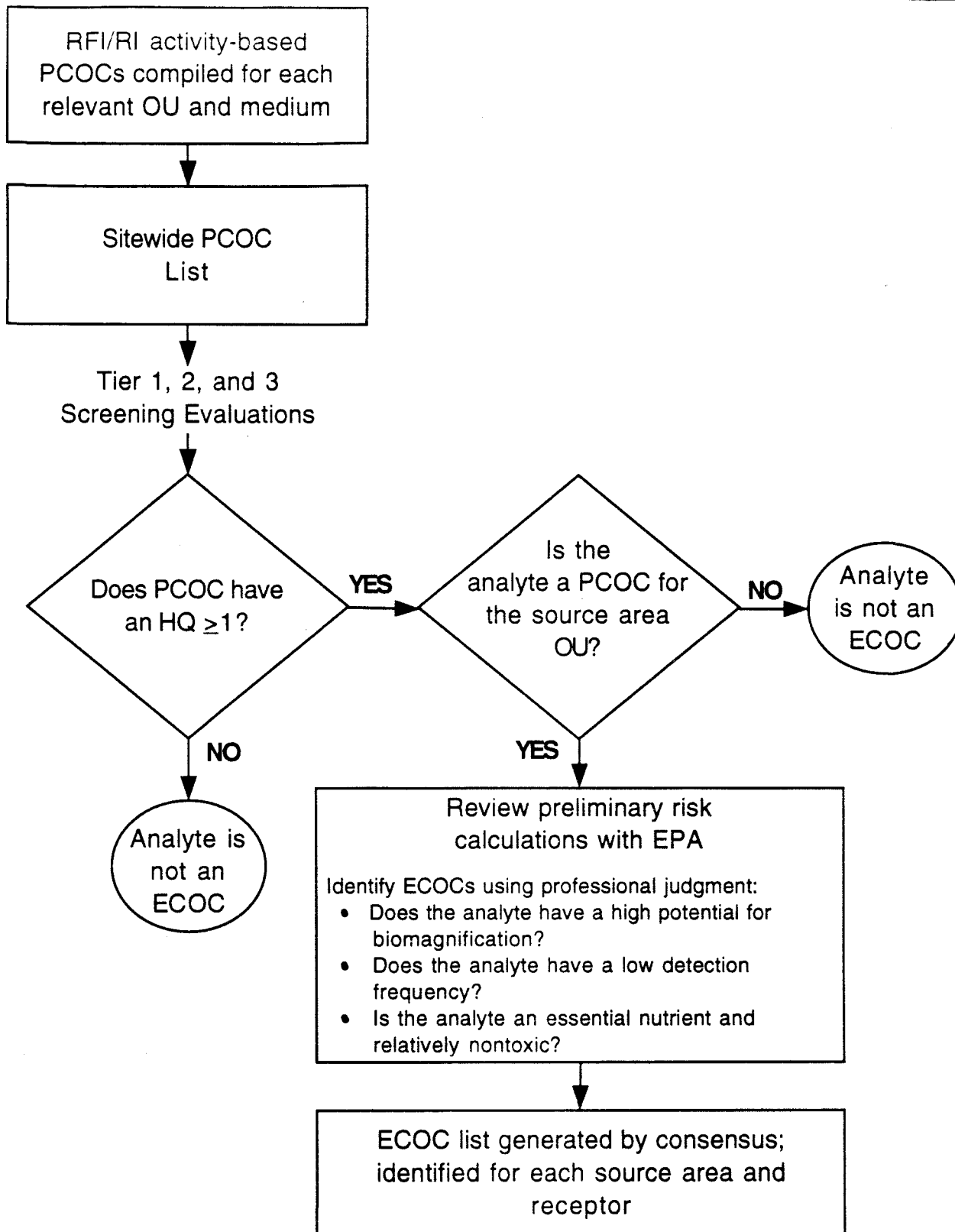


Cleanup Routine for Analytical Data

September 1995

Figure N3-8





U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

ERAs for Woman Creek and Walnut Creek
Watersheds at RFETS

**Determination Process for Ecological
Chemicals of Concern (ECOCs)**

September 1995

Figure N3-9

Figure N3-12
Summary of Ecotoxicological Risk to Preble's Meadow Jumping Mouse

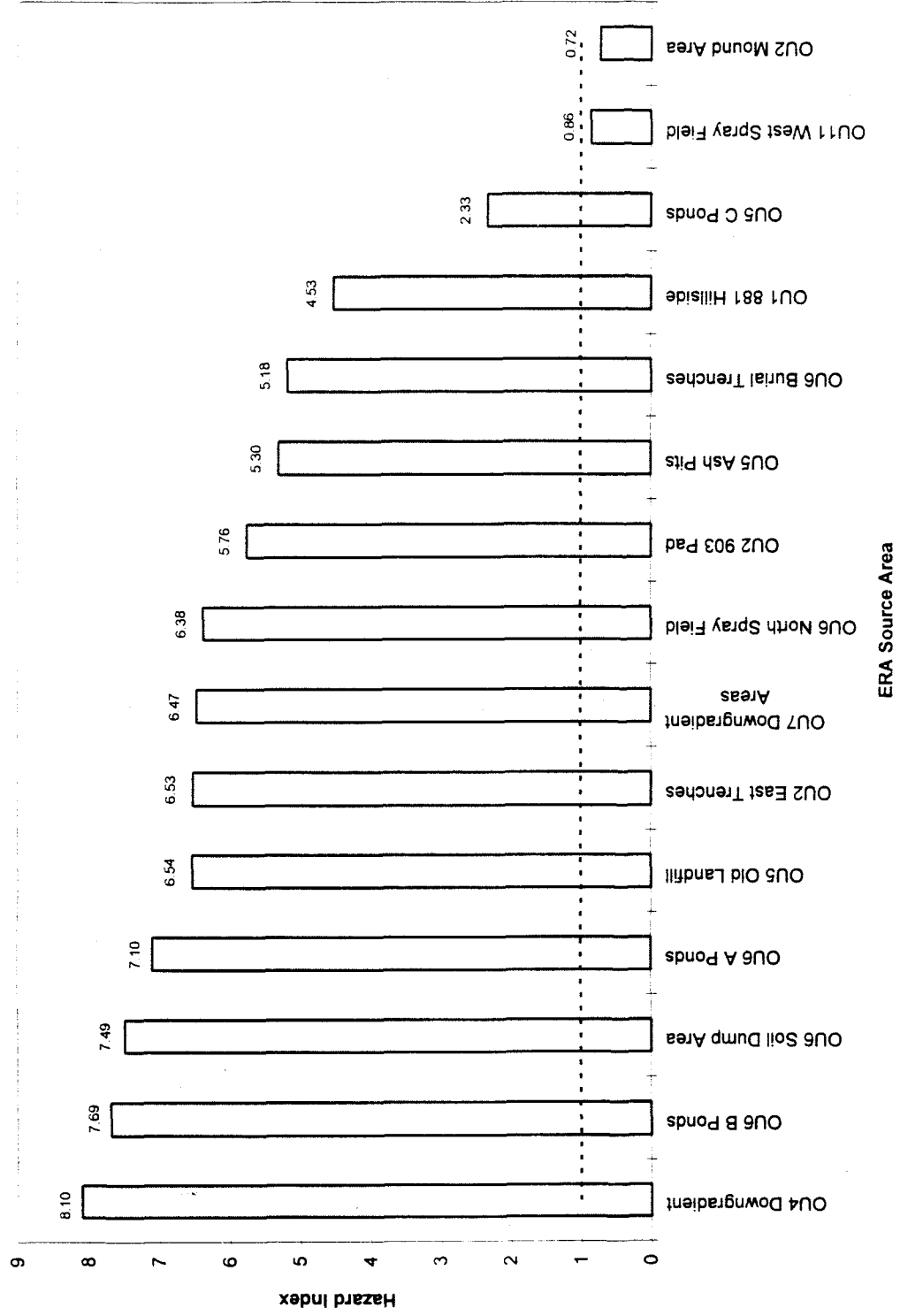


Figure N3-13
Summary of Ecotoxicological Risk to American Kestrel

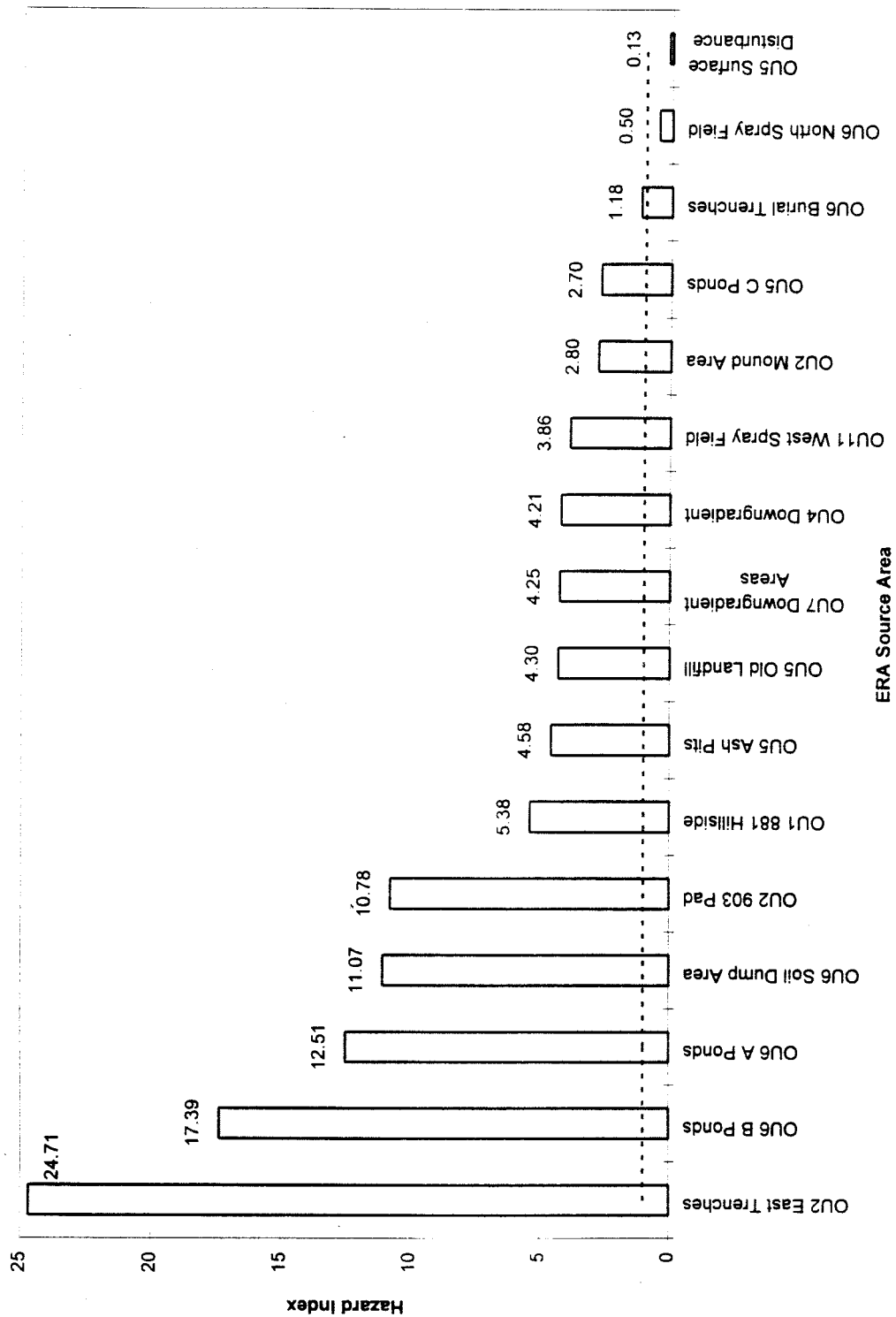


Figure N3-14
Summary of Ecotoxicological Risk to Great Blue Heron

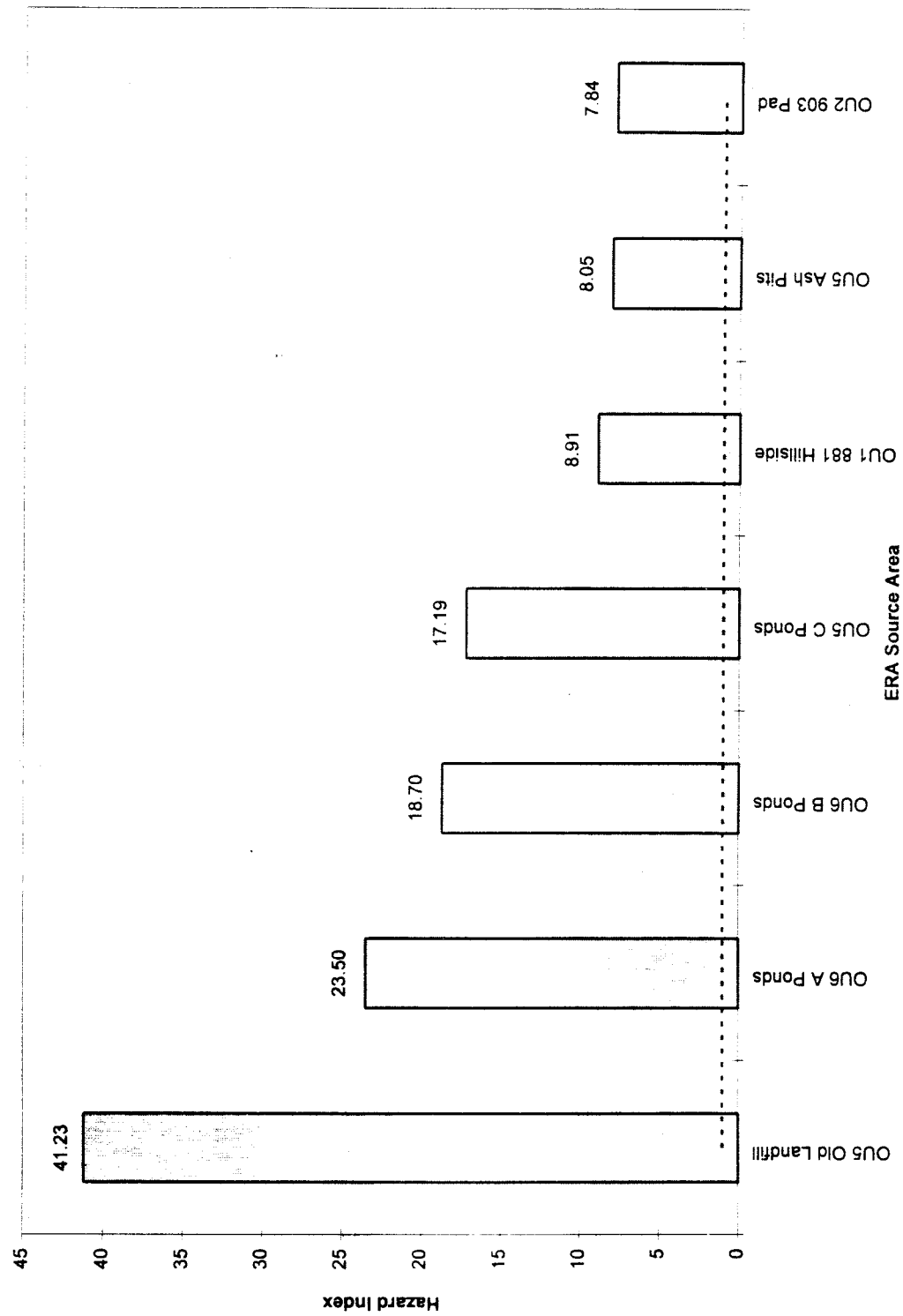


Figure N3-15
Summary of Ecotoxicological Risk to Mallard

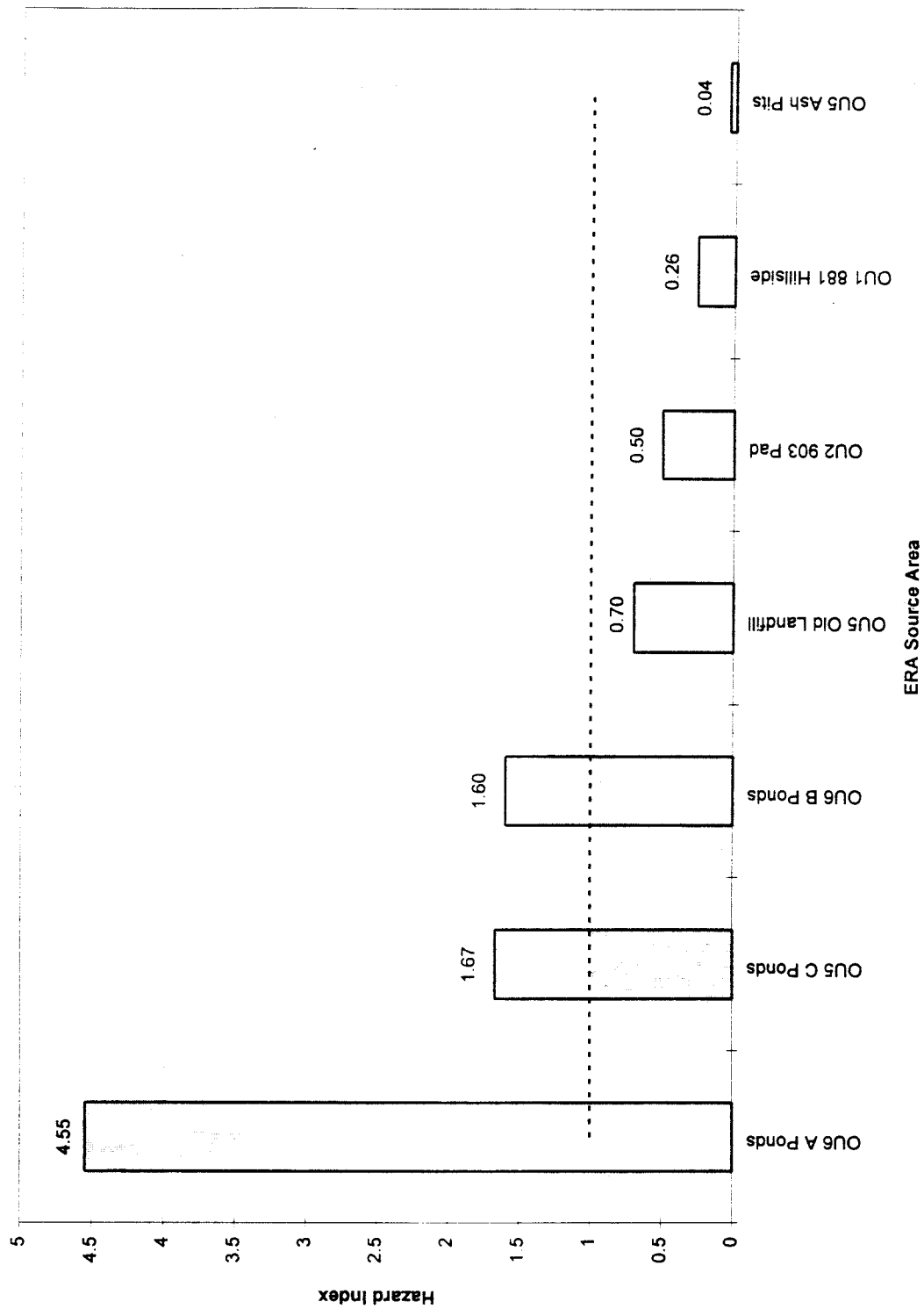


Figure N3-16
Summary of Ecotoxicological Risk to Mule Deer

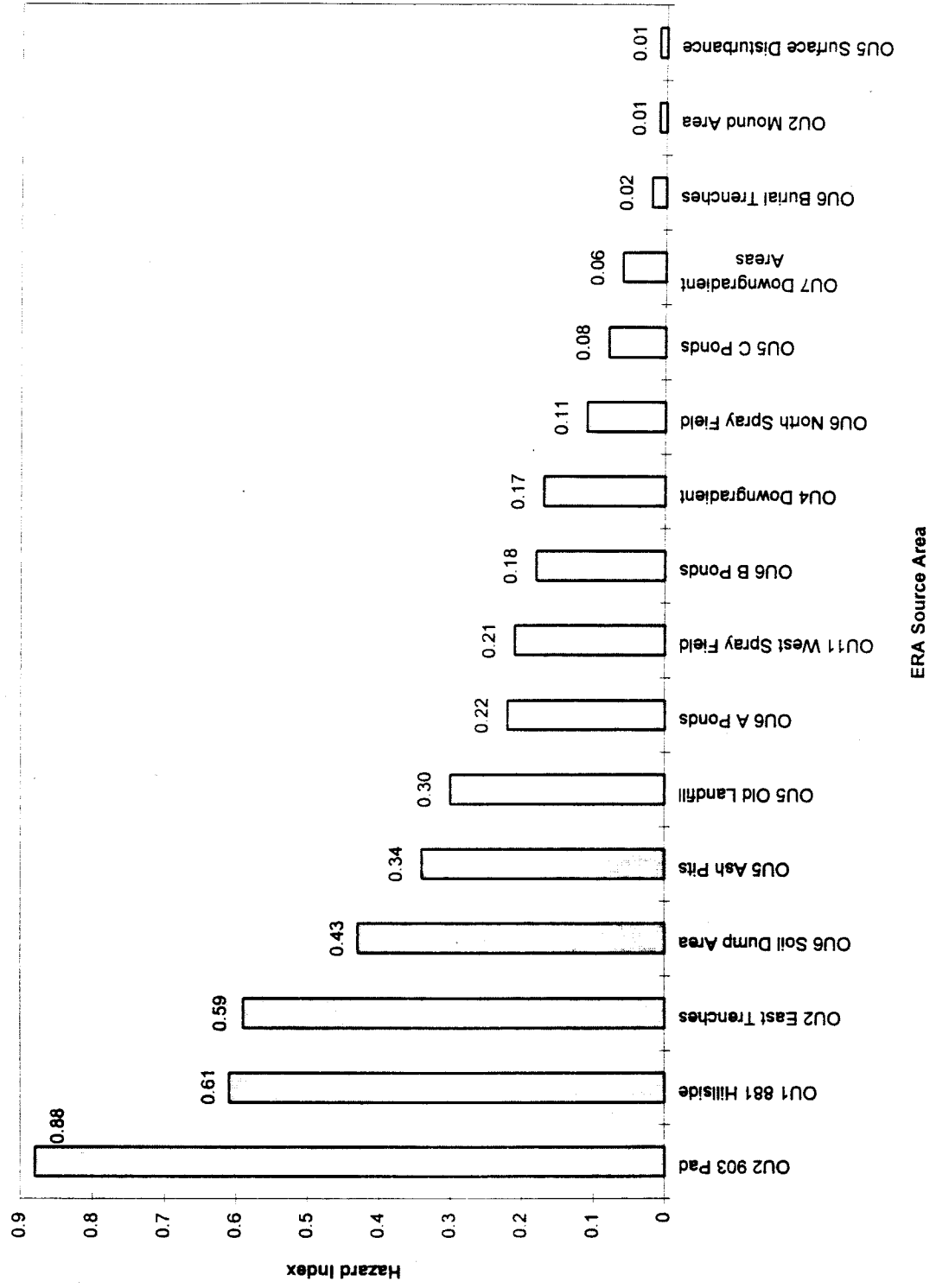


Figure N3-17
Summary of Ecotoxicological Risk to Coyote

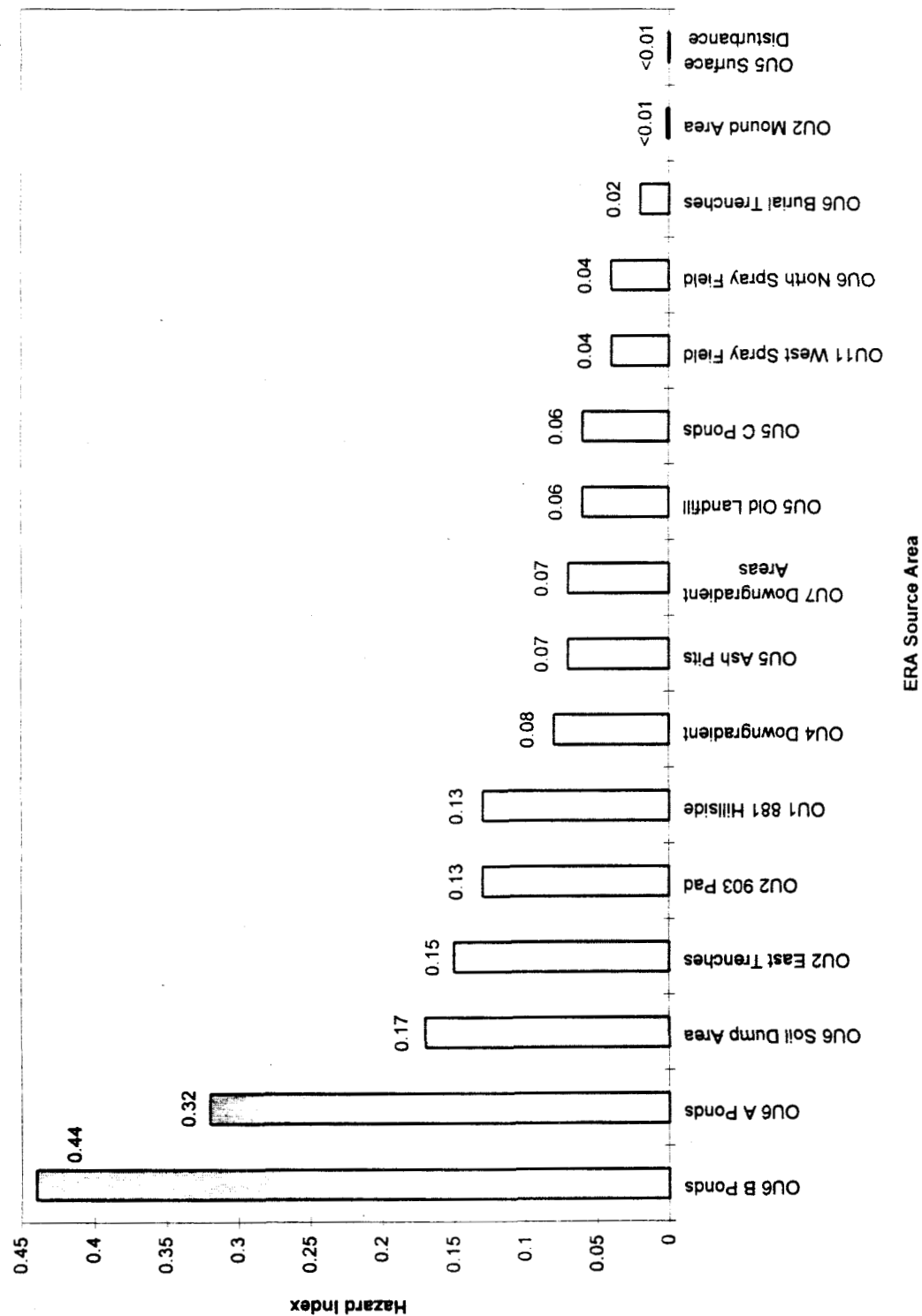
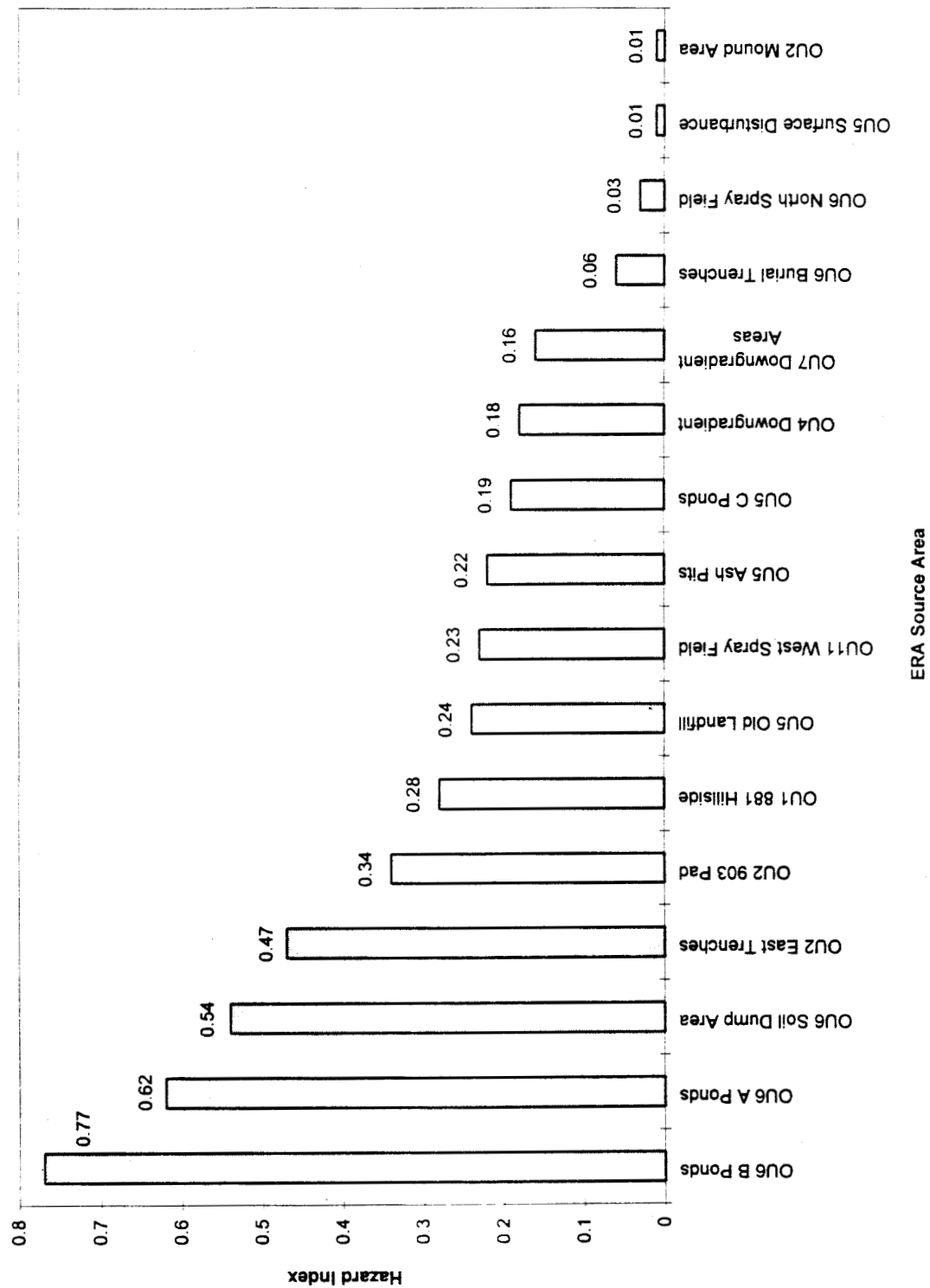


Figure N3-18
Summary of Ecotoxicological Risk to Red-tailed Hawk



N4. Problem Formulation

The Tier 3 screen identified ECOCs based on chemical concentrations in abiotic and biotic media and conservative assumptions concerning exposure and toxicity. The remainder of the ERA focuses on further characterization of ecological risk from exposure to the ECOCs. The purpose of problem formulation is to establish the specific objectives and approach for risk characterization (EPA 1994). The problem formulation phase of this ERA describes methods by which existing data were used in risk characterization. Results of analyses and risk characterization are presented in Section N5.

The risk characterization has two main goals: (1) refine risk estimates through use of less conservative and more realistic assumptions and characterize remaining uncertainty and (2) identify areas, chemicals, and media contributing most to risk. Where feasible, guidance for developing cleanup criteria protective of assessment endpoints is also provided. Where appropriate, exposures and risk are summarized by watershed, OU, and IHSS to aid in risk management and remediation decisions.

Conservative assumptions were used in the Tier 3 screen to improve efficiency of the screen or to account for uncertainty in exposure or toxicity estimates. Conservative assumptions were selected to minimize the probability of underestimating risk so that uncertainty would be biased in only one direction (EPA 1994). Refinement of risk estimates involved use of less conservative assumptions and/or site data on direct measurement of toxic effects to reduce uncertainty. In most cases, a combination of data types was used in a weight-of-evidence approach to risk characterization.

The risk characterization for each of the ECOCs included the following activities: (1) refine exposure estimates to more accurately reflect site conditions, including bioavailability, contaminant distribution, and frequency and duration of exposures; (2) refine toxicity estimates based on more specific evaluation of contaminant forms and potential toxicity; (3) review site data to determine if predicted effects were manifested; (4) if appropriate, extrapolate effects on individuals to estimate effects to RFETS populations or communities; and (5) identify, characterize, and rank sources of uncertainty and identify data needed to further refine estimates.

The risk characterization focused on potential toxic effects of ECOCs to five ecological receptor groups:

1. Aquatic life
2. Aquatic-feeding birds

3. Terrestrial-feeding raptors
4. Small mammals
5. Vegetation communities

These receptor groups were selected based on results of the ECOC screen presented in Section N3, either because potential toxicity from ECOCs was identified or because available data were inadequate to conclude that risk was negligible. Each group represents a category of ecological receptors for which potential risk was identified in Section N3 and further risk characterization is needed. Potential effects of radionuclides on plants and wildlife were evaluated separately.

Assessment endpoints and specific objectives of the risk characterization were identified for each resource category (Table N4-1). Assessment endpoints are explicit expressions of the environmental values to be protected (Suter 1989, EPA 1992a). The purpose of assessment endpoints in this phase of the ERA is to focus the risk characterization on chemical contaminants that are present at potentially toxic concentrations and specific effects that may result from exposure. The potential for exposure and toxicity was established in the Tier 3 screen. In most cases, the specific effect is defined by the toxicological endpoints on which the TRVs were based. Most of these endpoints were based on chronic sublethal or reproductive effects that were not measured at RFETS. Results of toxicity testing or other measurements of effects were available for some groups and were used where appropriate.

For each receptor group, assessment endpoints, exposure pathways, and specific goals and objectives are identified. Where appropriate, a working null hypothesis (H_0) was defined to help guide analysis and evaluation of uncertainty.

N4.1 Aquatic Life

As described in Section N2, aquatic habitats at RFETS have been highly modified by diversion and impoundment of water, which occurred historically for agricultural use and, more recently, for control of potential offsite transport of contaminants in water and sediments. Prior to agricultural development, Walnut Creek and Woman Creek were seasonally intermittent streams fed primarily by snowmelt and runoff. Aquatic communities were limited by both the periodic lack of flows and the generally low flows. Reliable surface flows occur only near seeps and springs.

Construction of detention ponds in both watersheds severely altered the natural hydrologic conditions. Creation of the ponds resulted in permanent lentic (standing water) habitats in areas where water previously was present only seasonally. In Walnut Creek, batch-release of water from the terminal ponds (Pond A-4 and Pond

B-5) has caused stream segments immediately downstream to be dry most of the time. Establishment of aquatic life in these stream segments is limited because batch-releases are of short duration and occur at irregular intervals. Much of the water in Woman Creek has historically been diverted to Mower Ditch, leaving the segment below Pond C-2 dry much of the year. Flow in portions of Woman Creek upstream of Pond C-2 is relatively natural, although some groundwater sources may have been interrupted by installation of the SID and French drain in OU1 and OU5.

Stream communities at RFETS are composed of species that are typical of limited-flow or seasonal-flow environments. Under these conditions, assessment of impacts due to contaminant input is difficult because of natural variability. Several years of monitoring data and suitable upstream reference sites are necessary to identify community impacts; such data do not currently exist for RFETS.

Physical conditions in the ponds also hinder assessment of toxic impacts. Water levels in Ponds A-3, A-4, B-2, B-3, and B-5 are manipulated for site water management (DOE 1995a). Ponds A-1, A-2, B-1, and B-2 are relatively shallow (less than 1 m), have no regular input besides local runoff, and have no regular output besides evaporation. As a result, the ponds have abundant aquatic plant life. However, faunal communities are limited, probably because of high daytime temperatures (in summer) and low dissolved oxygen at night. Pond B-3 receives output from the site wastewater treatment plant, and un-ionized ammonia has been cited as a potential toxicant in the past (Wolaver 1993).

Because the physical conditions in stream and pond communities hindered definitive identification of toxic effects in the ERA, a weight-of-evidence approach was used to evaluate potential toxicity. The approach included evaluation of chemical concentrations in sediments, review of screening-level TRVs for applicability to the sites, results of laboratory toxicity tests, and data on benthic and pelagic community composition.

N4.1.1 ECOCs

ECOCs for aquatic life were primarily associated with sediments and included metals and SVOCs (Tables N3-20 and N3-22). Screening-level risk estimates indicated that PAHs and silver were the ECOCs contributing most to potential toxicity in sediments (Table N3-22).

N4.1.2 Assessment Endpoints and Specific Objectives

Assessment endpoint:

⇒ *Determine whether sediment ECOCs could result in toxicity to benthic fauna, fish, or amphibians sufficient to limit the aquatic communities in the ponds.*

The toxicity evaluation was conducted assuming that physical conditions are not limiting.

The risk characterization focused on addressing two main questions:

1. Are concentrations of ECOCs in sediments above levels toxic to aquatic life? (H₀: sediment ECOC concentrations less than TRVs)
2. Do results of community surveys and toxicity testing indicate the toxicity predicted by the preliminary exposure and risk characterization? (H₀: community composition degraded with respect to areas not impacted by sediment contamination; H₀: toxicity of site sediment samples less than controls)

The potential for introduction of groundwater contaminants into surface water onsite was also evaluated using information on groundwater movements and contamination. This evaluation did not include quantitative modeling of groundwater transport. Rather, the evaluation was conducted by comparing maximum concentrations of groundwater PCOCs to water-quality standards and identifying the stream segments or ponds toward which contaminant plumes are moving.

The following specific objectives were addressed in the analysis:

- *Evaluate results of sediment and water toxicity tests.* Toxicity tests were conducted using sediments from each of the A-, B-, and C-series ponds and from stream locations in Woman Creek that were downgradient of OU5 IHSSs. Tests were conducted using *Hyaella azteca* and *Chironomus tentans*. In addition, acute toxicity screens and whole-effluent toxicity tests were conducted for water using fathead minnows and *Ceriodaphnia* sp. These data were used to help determine whether the levels of toxicity predicted by the HQs in the preliminary risk calculations correspond to results of toxicity tests.
- *Evaluate aquatic community composition.* Community data on benthic macroinvertebrates, fish, and plankton were collected from each of the impoundments at RFETS using quantitative methods. These data were used to evaluate potential toxic impacts in two ways: (1) standard measures of community composition and presence/absence of sensitive/tolerant taxa were

used to assess the potential toxic effects and (2) although data from strictly comparable reference areas were not available, community data were evaluated using data on communities in nearby stock ponds (D-series ponds) as indicators of potential community structure.

- *Compare ECOC concentration in sediments to TRVs.* Data on chemical concentrations were used to estimate exposures and characterize distribution of ECOCs in sediments. The relationship between community measures and toxicity predicted from preliminary risk screens was evaluated to determine whether a “dose-response” relationship between ECOC concentration and adverse effects on pond communities was apparent.
- *Determine ECOC concentration in biological tissues.* In some cases, concentrations of ECOCs in invertebrate or fish tissues were compared to information concerning concentrations known to cause adverse effects. Tissue data were also used to characterize site-specific uptake ratios between ECOC concentrations in biota and sediments. Estimated uptake ratios were then used to approximate the levels to which contaminants might accumulate in ponds that currently lack well-developed aquatic communities.
- *Characterize contaminant concentrations in groundwater.* PCOC concentrations in groundwater were summarized for IHSS in OUs 1, 2, 4, and 5. Maximum concentrations were compared to surface water quality standards because of the potential for groundwater to enter surface-water systems. Information on groundwater flow patterns at RFETS was used to identify stream segments and ponds that may receive contaminant input from groundwater.

N4.2 Aquatic-Feeding Birds

Aquatic habitats created by the construction of detention ponds at RFETS attract a variety of wildlife. Although many of the ponds lack a well-developed aquatic community (DOE 1995d), species such as raccoons, mule deer, black-crowned night-herons, great blue herons, and waterfowl have been observed feeding and drinking from the ponds and thus may be exposed to contaminants in surface water and sediments. Stream and ditch habitats at RFETS are also occasionally used by these species.

Birds and mammals that feed in aquatic habitats may experience higher contaminant exposures than their terrestrial-feeding counterparts. This is primarily due to three factors:

1. Erosion and groundwater transport may cause contaminants to accumulate and focus in watersheds.

2. Patches of aquatic habitats are usually small relative to terrestrial areas, and aquatic-feeding wildlife tend to concentrate around suitable habitat. Thus, use of aquatic habitats can be disproportionately high compared to areal extent.
3. Bioconcentration and bioaccumulation of chemicals in aquatic organisms can lead to toxic exposures even when concentrations in abiotic media are relatively non-toxic or when contact with the contaminated media is limited (e.g., sediments).

Aquatic-feeding birds and mammals are attracted to pond habitats at RFETS and therefore could also be exposed to sediment or surface water contaminants. Preliminary risk estimates indicate that current concentrations of ECOCs in sediment and biota are probably non-toxic (Section N3 and Stiger 1994). However, ponds with the highest PCB concentrations apparently do not support significant fish or amphibian populations. More extensive colonization of the ponds could result in more complex food webs, increased biological transport of sediment contaminants, and exposure of birds or mammals to higher concentrations in biota. The risk characterization includes evaluation of potential exposures as well as those based on existing conditions.

The mallard and great blue heron were selected to represent aquatic-feeding wildlife because they are common species in the area and are known to occur at RFETS. In addition, birds are more sensitive than mammals to organic contaminants because they lack the same capacity for detoxification and therefore represent a more limiting exposure and risk scenario.

Hérons feed primarily on fish. Amphibians and invertebrates are usually minor components of their diets but can be important in localized areas. Herons have relatively little direct contact with sediments during feeding. Mallards have more contact with the sediment because they may feed by filtering plant material and invertebrates. However, the amount of sediment ingested by mallards does not greatly exceed that of other more selective feeders (EPA 1993a). Thus, the primary pathway for exposure of both birds to PCBs in sediments is through ingestion of aquatic organisms that have become contaminated. Estimating exposure of herons and mallards requires measurement of concentrations in biota or estimating transfer of PCBs from sediments to prey species.

N4.2.1 ECOCs

ECOCs identified in Section N3 include Aroclor-1254 and PAHs in sediments and DBP in surface water. As noted above, screening-level exposure and risk calculations indicated minimal risk from PCB concentrations in sediments and biota under current conditions. However, biological samples were not available

from the ponds with highest concentrations in sediments, and further evaluation of potential exposure and risk was needed because of the high potential for bioaccumulation of these contaminants. DBP was identified as an ECOC due to its potential for bioconcentration in the aquatic prey of mallards and herons (Table N3-20). DBP concentrations in aquatic biota were estimated from BCF and surface water data. This approach was necessary because biological samples were not analyzed for this compound and therefore tissue data were not available for exposure analyses.

For all three ECOCs, the primary exposure pathway of concern was ingestion of contaminants in food.

N4.2.2 Assessment Endpoints and Specific Objectives

Assessment endpoint:

⇒ Determine if ECOC concentrations in surface water and sediments of the detention ponds could result in exposures that reduce the survivorship or reproductive capacity of aquatic feeding birds. (H₀: exposure less than TRV)

The risk characterization was based on exposure and risk to individual birds because great blue heron and mallard are protected under the Migratory Bird Treaty Act.

The exposure and risk evaluation was conducted for mallards and great blue herons under two exposure scenarios: (1) current and aquatic community structure and contaminant distribution; and (2) more complex aquatic communities that could result in increased biological transport of sediment contaminants and increased PCB concentrations in prey. Several of the ponds that have PCBs in sediments currently lack fish or productive littoral zones. Introduction of fish or an increase in primary production could result in completion of exposure pathways that are currently incomplete. The basis for use of site-specific data in predicting potential concentrations in aquatic prey is described in the following paragraphs.

Because of their high hydrophobicity, many organic contaminants in aquatic environments tend to adsorb to sediment particulates and are distributed primarily by bulk transport of sediment. Aquatic organisms can take up PCBs from sediments through direct contact with sediments and interstitial waters or through ingestion of contaminated food. The former pathways are most important for benthic invertebrates and fish that have more direct contact with sediments. Food chain transfer is more important for more pelagic organisms, such as fathead minnows and largemouth bass (Thomann 1981, Rassmussen *et al.* 1990, Macdonald *et al.* 1993).

Distribution of PCBs in sediments and aquatic biota is determined by their hydrophobicity. In animals, persistent hydrophobic organics such as PCBs are found primarily in fat or other high-lipid tissues. In sediments, PCBs partition into the organic carbon component, which includes detritus and micro-organisms. Transfer from sediments to the benthic infauna is controlled by the rate of desorption from sediment particles into interstitial water (Landrum and Robbins 1990). As a result, the concentration of PCBs in the lipids of benthic fauna is generally equal to that in the organic carbon component of the surrounding sediment (Di Toro *et al.* 1991). PCB concentrations in higher organisms are more difficult to predict because the primary intake mechanisms are more complex and may vary among sites (Macdonald *et al.* 1993). The magnitude of bioaccumulation in aquatic communities is usually proportional to the length of the food chains (Rassmussen *et al.* 1990). Therefore, concentrations of organic contaminants in aquatic predators such as bass tend to vary with the complexity of local food webs.

Exposure of herons and mallards to Aroclor-1254 was estimated from site-specific data on PCB concentrations in sediment and biota. Current exposures were estimated using PCB concentrations measured in biota samples from individual ponds. Field surveys indicate that fish or other important prey may be lacking in some ponds. For these sites, potential exposures were estimated using biota-sediment PCB concentration ratios that were based on data from ponds for which biota and sediment data were available. Tissue PCB content was estimated from the ratio of concentrations in biota lipid to that in the organic carbon of sediment (bioconcentration sediment factor [BSF]) (Macdonald *et al.* 1993). These data were also used to estimate sediment cleanup criteria by estimating the concentration of PCBs in sediments that would result in exposures equal to the TRVs for mallards and herons.

The following specific objectives were addressed in the analyses:

- *Estimate current exposure using ECOC concentrations in sediment and biota.* Exposures were estimated for each pond in which contaminants were detected.
- *Estimate site-specific biota:sediment PCB concentration ratios.* Data from ponds where both sediment and biota samples were collected were used to calculate ratios of Aroclor-1254 concentrations in biota to those in sediment. Ratios were calculated for whole-body:bulk sediment and lipid:sediment organic carbon. The latter ratio was used to estimate uptake and tissue concentrations in ponds that currently lack fish.
- *Develop remediation criteria for sediments.* Concentrations of Aroclor-1254 in sediment that would be protective of aquatic birds were estimated from the site-

specific concentration ratios. Criteria were calculated for a range of site-use scenarios to aid in decisions on remedial actions.

- *Evaluate exposure of receptors to DBP in aquatic prey.* Concentrations of DBP in abiotic media were used in each pond where they were detected. Bioconcentration of DBP was estimated for each pond using surface water data.

N4.3 Terrestrial-Feeding Raptors

Raptors that feed on terrestrial organisms may be exposed to contaminants that bioaccumulate in prey or through ingestion of contaminated soil or water. The Tier 3 screen included evaluation of two raptors: the red-tailed hawk and American kestrel. Risks to red-tailed hawks were negligible. However, the screen identified potential risks to kestrels from metals in small mammal and invertebrate prey species in source areas in upper Walnut Creek from OU2, OU4, and OU6.

American kestrels feed on a wide variety of small mammal and invertebrate prey, and their foraging ranges are small relative to other falcons and hawks. Kestrels are common along the Front Range and have been observed foraging in nearly every vegetation community type at RFETS, including areas of upper Walnut Creek. The species has also been observed nesting in abandoned buildings in the buffer zone (DOE 1995d). Kestrels represent a limiting exposure scenario for raptors at RFETS because individuals may spend most or all of the breeding season onsite and forage in potentially contaminated areas.

N4.3.1 ECOCs

ECOCs identified for kestrels were chromium, lead, mercury, and vanadium. Risks in OU2 were primarily due to chromium concentrations in invertebrates. Risks in OU6 were due to chromium, lead, mercury, and vanadium in small mammals.

The initial phase of the risk characterization evaluated the data used in screening-level exposure estimates. Mercury and vanadium were detected at low frequencies in small mammals from the Walnut Creek area. The frequency of chromium detection in terrestrial invertebrates from OU2 was also low. The uncertainty associated with using the maximum detected metal concentrations for the preliminary exposure estimates was evaluated and summarized qualitatively. Chromium was included in the OU6 PCOC list based on a single soil sample that exceeded the UTL_{99/99} (DOE 1994e). However, chromium and lead concentrations were elevated in small mammals captured in the Walnut Creek watershed. Exposure of kestrels to chromium and lead in small mammals from the Walnut Creek watershed and RFETS background areas was evaluated using probabilistic methods.

N4.3.2 Assessment Endpoints and Specific Objectives

Assessment endpoint:

⇒ *Determine the likelihood that individual kestrels will experience toxic exposures that will significantly reduce their survivorship or reproductive capacity. (H_0 exposure less than TRV)*

The risk characterization focused on refining exposure estimates through evaluation of data used in preliminary risk screens; exposure estimates were based on individual birds. Results of the risk characterization were calculated for individual birds and qualitatively extrapolated to the RFETS population.

The following specific objectives were addressed in the analyses:

- *Assess representativeness of data on metal content of potential prey.* Analytical data were reviewed to determine the reliability of the screening-level risk estimate. Detection frequency, spatial distribution, and range of concentrations were considered in the assessment.
- *Estimate probability of exceeding TRV in Walnut Creek source areas.* The probability that a kestrel feeding in the A- and B-pond areas would exceed TRVs for lead and chromium was estimated using Latin hypercube simulation procedures (Bartell *et al.* 1992) and data on metal concentrations in small mammals from the OU6 A-Ponds, OU6 B-Ponds, and OU4 Downgradient source areas. Only the distribution of metal concentrations was modeled; all other intake parameters were fixed at levels consistent with EPA guidance (EPA 1993a). Exposure analyses were based on total metal concentrations in prey.

N4.4 Small Mammals

Small mammals represent a limiting exposure scenario for omnivorous vertebrates because they (1) are in relatively constant contact with soils, the primary contaminated media at RFETS, and (2) have home ranges sufficiently small that they may spend all of their time within a single source area.

Evaluation of risk to small mammals was based on exposure of individuals to ECOCs through ingestion or inhalation. The risk evaluation was based on individual animals because of the presence of PMJM at RFETS. As noted in Section N2, PMJM is of special concern at RFETS because it is listed as a Category 2 species by USFWS. Although this subspecies is primarily associated with riparian corridors, it has been captured in upland areas of RFETS and may be

exposed to chemical stressors in grassland habitats such as in the IHSSs in OU2 and OU6.

N4.4.1 ECOCs

The preliminary risk calculation indicated relatively low risk to PMJM from ingestion of PCOCs. Selenium and barium were identified as ECOCs in single source areas (Table N3-20). Exposure to volatilized organic contaminants in soils was also evaluated. However, little information was available for evaluating the potential toxicity of respiratory exposures (Attachment 6, Table 9 and Table 10).

N4.4.2 Assessment Endpoints and Specific Objectives

Assessment endpoint:

⇒ *Determine the likelihood that individual animals will experience toxic exposures that will significantly reduce their survivorship or reproductive capacity. (H₀: exposure less than TRV)*

The following specific endpoints were addressed in the analysis:

- *Estimate contaminant intake from soil.* Intake of selenium and barium from soils was estimated as in the Tier 3 screen. The distribution of selenium and barium was evaluated to determine whether or not more accurate assumptions about bioavailability and frequency and duration of exposures can be applied. Relative risks were re-evaluated based on new estimates.
- *Evaluate TRVs for selenium and barium.* Toxicity information for selenium and barium was reviewed to determine whether or not TRVs were overly conservative due to overestimates of bioavailability, underestimates of elimination rates, or sensitivity of test species versus RFETS receptors.
- *Estimate concentrations of volatilized organic compounds that could accumulate in burrow air.* Concentrations were estimated for areas of buried waste and known subsurface contamination. Exposure estimates were compared to toxicity information when available. However, little information was available on toxicity to mammals through respiratory pathways. Therefore, exposures were estimated and presented for evaluation until better toxicity information is developed.

N4.5 Vegetation Communities

Vegetation communities are the most important biological component that characterizes an ecosystem. Vegetation community structure is critical in determining the quality and suitability of wildlife habitats because plants provide

important food sources, refuges, and structural components. The vegetation communities in the RFETS buffer zone are important locally because they have been relatively undisturbed for more than 50 years and contain a large number of native species that are not common in more disturbed areas.

Areas of obvious phytotoxic stress were not observed during extensive field investigations. Many areas showed signs of physical disturbance associated with construction, remediation, or RFETS industrial activities. Therefore, the evaluation of potential ecotoxicity was based primarily on review of literature on phytotoxicity of PCOCs.

N4.5.1 ECOCs

Little suitable data on toxicity of chemical contaminants, particularly organic chemicals, to plants were available for assessing potential toxicity of PCOCs. In addition, the toxicity of a given chemical is usually highly dependent on soil chemistry and physical conditions. Therefore, toxicity thresholds are often not comparable between sites. Plant species also vary greatly in their sensitivity and potential for contaminant uptake.

As described in Section N3, preliminary risk estimates for vegetation were conducted based on comparison of PCOC concentrations in surface soils and sediments to available toxicity information. Numerous PCOCs were associated with HQs greater than 1 (Attachment 6, Tables 1 through 6). Soil and sediment PCOCs for which no toxicity data were available are listed with their concentrations (Attachment 6, Tables 7 and 8).

N4.5.2 Assessment Endpoints and Specific Objectives

Assessment endpoint:

⇒ *Determine if ECOC concentrations and the areal extent of contaminated subsurface soils (or sediments) could adversely affect more than 5 percent of any given vegetation community type at RFETS. (H_0 : concentration in subsurface soil less than TRV in 95 percent of samples from a given vegetation type)*

The following specific objectives were addressed in the analysis:

- *Identify sampling locations with ECOC concentrations that correspond to an HQ greater than 10. This level of toxicity was arbitrarily selected to identify sites with the greatest potential for phytotoxicity. ECOCs associated with an HQ greater than 1 are listed in Table N3-23. This approach seemed adequate because although the HQ for many PCOCs exceeded 1, the lack of obvious*

phytotoxicity in plants throughout the site seemed to indicate that TRVs were conservative.

- *Estimate area of contamination associated with HQ greater than 10 for any given ECOC.* Areas were visually identified based on sampling locations and chemical data. ECOC concentrations in sediment samples from pond and stream sampling sites were used to estimate exposure to wetland plants. The amount of each habitat type within the watershed represented by these affected areas was then estimated.

N4.6 Radiological Dose Rates

Transuranic radionuclides are important environmental contaminants at RFETS. The potential ecotoxicity of radionuclides in abiotic media was evaluated in the Tier 3 screen using TRVs developed specifically for RFETS by radioecologists from Oregon State University (Higley and Kuperman 1995). The Tier 3 screen indicated negligible risk from most areas of the site. However, because of the importance of radionuclide contamination at RFETS, the potential risk was also evaluated by a second method. Data on the radionuclide content of vegetation, small mammal, and aquatic biota samples were used to estimate internal radiological dose rates. These values were then compared to the 0.1 rad/day dose rates cited as safe by the International Atomic Energy Agency (IAEA) (1992) and used in deriving benchmarks for abiotic media (Higley and Kuperman 1995).

N4.6.1 Assessment Endpoints and Specific Objectives

Assessment endpoint:

⇒ *Determine whether or not uptake of radionuclides by biota at RFETS could result in concentrations that exceed TRVs for radiological dose rates.*

The following specific objectives were addressed in the analysis:

- *Estimate radiological dose rates from data on ECOC concentrations in biological samples.* Dose rates were estimated for each of the major transuranic radionuclides using the equation (Whicker 1993):

$$\text{Dose (rad / day)} = \frac{C_{\text{tissue}} \times DR_x \times E_x \times 1.6 \times 10^{-6} \text{ ergs / MeV} \times 1,440 \text{ min / day}}{100 \text{ ergs / g - rad}}$$

where:

$C_{\text{tissue},x}$ = concentration of radionuclide x in tissue samples (pCi/g)

Dr_x = disintegration rate for radionuclide x (dis/min)

E_x = effective absorbed dose for radionuclide x (MeV/dis)

- *Estimate potential accumulation of radionuclides by predators.* Potential uptake and accumulation of radionuclides by predators feeding at RFETS was also estimated using biological tissue data and the equation:

$$\text{Tissue Concentration} = \frac{C_f \times \text{FIR} \times a}{bw \times k_e} \times (1 - e^{-k_e t})$$

where:

C_f = concentration in food (pCi/g)

FIR = food ingestion rate (kg/day)

a = assimilation rate (unitless)

bw = body weight (kg)

k_e = coefficient of elimination (per day)

t = time (days)

The radiological dose rate associated with the predicted tissue concentrations was calculated using the equation on the previous page. Dose rates were compared to the TRV (0.1 rad/day) recommended by IAEA. Calculations were first conducted using site maximum concentrations (or activities). If maximum dose rates exceeded the TRV, all samples and locations with tissue concentrations exceeding critical levels were identified and mapped to determine probable abiotic sources.

CHAPTER N4

TABLES

Table N4-1
Summary of Assessment Endpoints and Measurement Endpoints for Risk Characterization

Type Receptor	Pathways	ECOCs	Endpoint Assessment	Endpoints Measurement	Null Working Hypothesis
Aquatic Life	Direct exposure to sediments	PAHs, PCBs, metals	Impacts to community composition	(1) toxicity to test organisms (2) community composition (3) correlation of concentration with endpoint (4) estimate bioaccumulation in fish tissue (PCBs)	(1) toxicity in site samples not greater than controls (2) communities different than D-Ponds (3) contaminant concentrations not correlated with biological effect (toxicity, community measures) (4) concentration in tissue not greater than TRV
Aquatic-Feeding Wildlife	Ingestion of contaminated food	Aroclor-1254 di-N-butyl phthalate	Potential toxicity to individuals, extrapolate to populations	(1) contaminant intake rate as estimated from: (a) measured concentration in prey species or (b) concentration in prey estimated from sediment data (2) develop site-specific remediation criteria	(1) intake rate not greater than TRV (2) N/A
Small Mammals	Ingestion of contaminants in prey and soils Inhalation of organic compounds in burrows	selenium, barium VOCs, SVOCs	Toxicity to individual <i>Z. h. preblei</i> Toxicity to individual <i>Z. h. preblei</i>	(1) contaminant intake as estimated from ECOC concentrations in soil, invertebrates, spatial distribution of ECOCs in soils (2) estimated concentration of organics in burrow air	(1) intake rate not greater than TRV (2) concentration in air not greater than TRV
Vegetation Communities	Direct exposure to contaminants in soils	metals, SVOCs	Impacts to community	(1) concentration of PCOCs in soils (2) area with potentially toxic levels of ECOCs	(1) concentration in soils not greater than TRV (2) area of potential toxicity is not greater than 5% of habitat in water-shed
Radionuclide Effects to Vegetation and Wildlife	Internal radiation dose rate	plutonium, uranium, americium	Toxic effects to individual small mammals and raptors; community effects to vegetation	(1) dose rates estimated from radionuclide concentration in tissues (2) estimated uptake and retention by predators	(1) calculated dose rates do not exceed TRV (2) estimated dose rates do not exceed TRV

ECOC - ecological chemical of concern
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
PCOC - potential chemical of concern
SVOC - semivolatile organic compound
TRV - toxicity reference value
VOC - volatile organic compound

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N5. Risk Characterization

This section presents results of analyses described in Section N4. Evaluations are presented for each of the ecological receptor groups identified in Section N4.1. In some cases, evaluation of ECOCs required different approaches and levels of quantification and necessitated separate presentation of results. The approach to risk characterization varied by receptor and chemical. Some analyses focused on evaluating RFI/RI data for accuracy and representativeness in estimating exposures. Other analyses provide more accurate exposure estimates through use of more sophisticated methodology than was used in the preliminary risk screen. Where appropriate and feasible, guidelines for establishing remediation criteria are presented.

N5.1 Aquatic Life

Detention ponds within the North Walnut Creek, South Walnut Creek, and Woman Creek watersheds have been constructed to minimize the offsite transport of sediment and waterborne contaminants at RFETS. The locations of the A-series ponds on North Walnut Creek, B-series ponds on South Walnut Creek, C-series ponds on Woman Creek, and reference-area Ponds D-1 and D-2 are illustrated in Figure N2-4. General physicochemical characteristics of these ponds are presented in Table N5-1. Although these ponds are variable in size and depth, they all are relatively shallow and thus are characterized by relatively warm water. Shallow conditions also result in thorough mixing as a result of wind effects; consequently, most of the ponds are also relatively well oxygenated.

Risks to aquatic life from chemical concentrations in sediments were evaluated by a weight-of-evidence approach. HQ and HI values from the Tier 3 screen indicate a relatively high potential for toxic effects in sediments. Characteristics of benthic community structure and results of sediment bioassay tests were used to check predictions of toxic stress as indicated by the screening results. Community characteristics, such as lower richness and diversity coupled with higher density of pollution-tolerant organisms, would be expected from locations having sediments with a potential toxic screen of PCOCs (high HQ and HI values). Similarly, sediment bioassay results should be consistent with estimations of sediment risk. Results of the sediment risk estimates, benthic community characterization, and sediment bioassay tests and relationships among these parameters are described below.

N5.1.1 Sediment ECOCs

Based on the ECOC screen, sediments in the detention ponds contain several metal and organic contaminants. HQs of individual PCOCs and pond HI values resulting from the sediment ECOC screen are presented in Attachment 4, Tables 1 through 4. In both the A- and B-series ponds in the Walnut Creek watershed, the highest HI values were calculated for the most upstream ponds. HI values for Ponds C-1 and C-2 in the Woman Creek watershed were approximately equal to each other and lower than for the Walnut Creek ponds (Figure N5-1).

HI values for the North Walnut Creek ponds ranged from 13 for Pond A-4 to 160 for Pond A-1. The North Walnut Creek stream location had an HI value of 180. For ponds in the South Walnut Creek watershed, the greatest risk to aquatic life was in Pond B-1, which had an HI of 2,000. The stream sediments in South Walnut Creek exhibited a higher HI value (230) than all ponds except Pond B-1. The lowest HI value of 8.0 was determined for Pond B-5. The C-series ponds had HI values of 2.6 for Pond C-1 and 3.0 for Pond C-2 compared to an HI value of 1.0 for the corresponding stream site in the Woman Creek watershed.

Analytes that contribute to the HI for each pond (Attachment 4, Tables 1 through 4) include metals, pesticides, PAHs, non-PAH semivolatiles, and volatile compounds. HQ values were calculated by pond for each of these chemical classes (Figures N5-2 through N5-4). With the exception of Pond C-2 and Woman Creek sediments, risks estimates are attributed primarily to PAHs, especially in ponds with moderate to high HIs (Figure N5-5, Table N5-2). Metals, which were detected in all pond sediments, were found to be the predominant toxicant in Pond A-4 and Woman Creek and represent about 40 percent of the total risk in Pond C-2. Although non-PAH semivolatiles accounted for half of the HI for Pond B-5, overall, pesticides, non-PAH semivolatiles, and volatiles were minor contributors to toxic risk.

N5.1.1.1 Benthic Macroinvertebrate Communities

Benthos samples were collected from all of the A-, B-, C-, and D-series ponds during May through July 1994. Five replicate multi-core composite samples were obtained from different water depths and submerged habitat types to ensure complete representation of the pond biota. Samples were analyzed for taxonomic composition and abundance; taxa were recorded at the lowest practical taxonomic level for the sample period.

A total of 81 different taxa representing all the major orders of aquatic organisms were identified in the pond benthos samples. A composite listing of identified taxa and mean abundance for each pond is presented in Attachment 8, Table 1. Oligochaete worms and dipterans dominated the benthos samples from all

locations. The B-series ponds contained the highest abundance of all taxa except Pelecypoda (snails), which were most abundant in the A-series ponds. The C-series ponds did not support a wide variety of organisms other than oligochaetes and dipterans.

Descriptive data for community parameters such as richness, density, Simpson and Shannon-Wiener diversity measures, number of dominant taxa (Hill's N1), and abundance-based relationships for oligochaetes and dipterans are presented in Table N5-3 for each pond. These data represent pond-level characteristics for a composite of data from the five different habitat samples.

Total richness ranged from 6 taxa in Pond C-1 to 48 taxa in Pond A-1. Mean density (for all organisms) ranged from a low of 66 organisms/m³ in Pond C-1 to 55,000 organisms/m³ in Pond B-3. Density of oligochaetes ranged from 39 organisms/m³ in Pond D-2 to 26,000 organisms/m³ in Pond A-3. Density of dipterans ranged from 25 organisms/m³ in Pond C-1 to 12,000 organisms/m³ in Pond B-4. Pond B-3 had the lowest diversity as indicated by the Simpson and Shannon-Weiner diversity indices (Table N5-3). The highest diversity was measured in Pond D-2 (Table N5-3). The Shannon-Weiner diversity coefficient varies with community richness and can be an unreliable measure of organism distribution for communities with low richness values (Washington 1984). Therefore, the maximum Shannon-Weiner diversity value (all organisms with equal abundance) for a given sample richness is also reported in Table N5-3 to more accurately describe differences in diversity among the samples.

Number of dominant taxa in each pond was determined using Hill's N1 coefficient (Ludwig and Reynolds 1988). Evaluation of the most common taxa facilitates ecological comparisons and interpretation because less emphasis is given to relatively rare species. Pollution tolerance values (TVs) are also commonly used to evaluate benthic communities for community health and biological responses to pollution stress (Hilsenhoff 1988, EPA 1989d, Clark and Maret 1993). A TV of 0 represents no tolerance to pollution, and a value of 10 is assigned to organisms most tolerant to pollution.

Dominant taxa, density-weighted TV, mean TV for dominant taxa in the pond, and rank of the weighted TV array are presented in Table N5-4. The density-weighted TV for each pond was calculated by dividing the dominant taxa density into the sum of the products of TV and percent density. TVs have traditionally been used for assessment of effects of pollution by organic compounds on macroinvertebrates. Density-weighted TVs presented here provide a relative measure for comparing community pollution tolerances among the ponds. Density-weighted tolerance values ranged from 5.2 for Pond A-1 to 8.9 for Pond A-2 (Table N5-4). Ponds A-1

and A-3 had the least pollution-tolerant communities of all ponds, including the D-series reference ponds. Ponds A-2 and B-2 had the most pollution-tolerant communities.

Conventional interpretation of benthic community structure suggests that communities with low densities of organisms or reduced richness and diversity are subject to physical or chemical stress. Under sustained chemical stress, the benthic community may also contain high densities of pollution-tolerant species, which in turn may result in low richness and low diversity. Benthic communities from Ponds D-1 and D-2 were sampled to represent locations with no known contaminant input from RFETS. Ponds D-1 and D-2 exhibit a wide range of community characteristics (Table N5-3), including the second lowest (Pond D-1) and highest (Pond D-2) diversity values.

Benthic community characteristics that would best reflect exposure to high-risk conditions include depressed richness or diversity and elevated density or abundance of tolerant species. A cursory review of the benthic community data indicates that Ponds A-4, B-3, and C-1 may be under the most persistent chemical or physical stress. In each of these ponds, oligochaetes and dipterans are the dominant taxa (Table N5-3, Attachment 8, Table 1). These organisms are considered good colonizers and frequently are the dominant taxa from habitats with high physical variability (Baxter 1977, Ward 1992). The highly variable environmental (physicochemical) conditions at RFETS may account for the dominance of colonizers.

Trends in benthic community data were compared to HQs to assess the extent to which communities are affected by chemical stress. Results of these comparisons are presented in Sections 5.1.4.

N5.1.1.2 Sediment Bioassays

Sediment toxicity tests were conducted on composite sediment samples collected from each pond during October and November 1992. Whole sediment tests following protocols outlined in Nelson *et al.* (1990) were used for 28-day exposure of the amphipod *Hyaella azteca* and 10-day exposure of the dipteran *Chironomus tentans*. Fine sands were used as controls. Sediments from the A-, B-, and C-series ponds were tested with *Hyaella azteca*. Toxicity tests using *Chironomus tentans* were limited to Ponds A-3, A-4, B-3, B-4, and B-5 due to reduced availability of acceptable test organisms. Toxicity test results reported here are based on information provided to the RFETS Surface Water Division in documents submitted by The Seacrest Group of Broomfield, Colorado. Further review of the toxicity test results may be necessary to evaluate test validity and statistical results.

Bioassay results for Pond B-2 sediments indicated that survival of *Hyaella azteca* after 28 days of exposure (64 percent) was significantly lower than in controls (85 percent) ($t=3.72$, $t_{0.05}=2.18$). No toxic effects were observed for *Hyaella azteca* or *Chironomus tentans* in any other sediment exposures. Table N5-5 presents a summary of the available bioassay test results.

N5.1.1.3 Sediment Effects on Aquatic Life

Risk to aquatic life from contaminants contained in sediments from the A-, B-, and C-series ponds was assessed by comparing toxicological sediment bioassay data and *in-situ* benthic community data to results of the sediment ECOC screen. This approach is similar to the Sediment Quality Triad procedure (Chapman 1986, EPA 1992c), which uses toxicity, chemistry, and benthic community data to investigate biological impact of sediment pollution and identify mechanisms of effects-based sediment studies (Chapman *et al.* 1992, Power and Chapman 1992, Canfield *et al.* 1994).

Evaluation of risk estimates was based on the following principles.

1. The sediment ECOC screening process resulted in a range in HI values of sufficient magnitude that differences in community-level effects to benthos and sediment bioassay test results can be expected among the sample sites.
2. Differences in community structure that typically reflect stress to the benthic assemblage will correspond to differences in HI values.
3. Statistically significant differences between treatments and controls in the sediment bioassay tests will correspond to differences in HI values among the sample sites.

Initial analysis of the data allowed identification of sites with benthic communities that are similar in composition and structure to sites with no known exposure to contaminants (Pond D-1 and Pond D-2). Cluster analysis (Ludwig and Reynolds 1988) was used to combine sites in hierarchical order of similarity based on density data for each taxon within the community. A conservative approach was taken by excluding data from Pond D-1 in this analysis.

Although the sediments from Pond D-1 are considered to be uncontaminated, the low richness and diversity and the high abundance of a single taxon at this site appear to reflect some type of environmental stress. The Bray-Curtis Percent Dissimilarity (PD) index was used to establish a level of resemblance for each pair-wise comparison among the sample sites. This measure of similarity is preferable because it utilizes a comparison of abundance data for shared taxa between two sampling sites. The matrix of pair-wise comparisons for all combinations of

samples was transformed to a matrix of mathematical distance measures and grouped by flexible clustering strategies to minimize distortion from original distance values. A complete discussion of the applications and calculations of the PD index and cluster analysis techniques can be found in Ludwig and Reynolds (1988).

A dendrogram depicting relationships among the sites based on PD comparisons of density is presented in Figure N5-6. The matrix of PD values is presented in Attachment 8, Table 2. The dendrogram depicts three distinct groups: Ponds A-2, A-4, and B-2; Ponds A-1, A-3, B-1, and B-5; and Ponds B-3, B-4, C-1, C-2, and D-2. The benthic communities that show greatest resemblance to the community characteristic for Pond D-1 include Ponds B-3, B-4, C-1, and C-2.

The ponds grouped with Pond D-2 on the dendrogram were used to evaluate the correlation of HI values with benthic communities structure. HI values ranged from 3 for Pond C-2 to 251 for Pond B-4 (Attachment 4, Tables 1 through 4). The HI for Pond B-4 (251) was the second highest among all ponds. Groups identified by this clustering do not correlate to clusters derived using HIs (Figure N5-7). This result suggests a lack of correlation between diversity and HI estimates.

Differential sensitivity of community structure to effects from exposure to contaminated sediments is obscured in the comparisons above. Cluster analysis techniques were used to determine the relationship between the HI estimate and community structure for each pond. Cluster dendrograms were also generated for benthos richness, diversity (Shannon-Weiner), density, and abundance-weighted TVs for dominant taxa; these are presented in Figures N5-8 and N5-9. Matrices for each of the cluster diagrams are included in Attachment 8, Tables 3 through 7. It is clear from the site groupings that none of the community structure parameters mirror the HI site grouping pattern. This result suggests a lack of correlation between the magnitude of the HIs and pond benthic community structure.

Agreement between measures of community structure and predicted toxicity was also assessed by evaluating correlations between community parameters and HIs and between the ranks for each parameter. The strength of the correlation between measured values and HIs or ranks was used to indicate the predictive power of HIs in assessing toxicity in the ponds.

Correlation between ranks indicates that 50 percent of the difference in richness and 46 percent of difference in density of the benthic community may be accounted for by differences in HI (Table N5-6). Use of ranks in evaluating correlations is intended only to identify trends in the relationships between community parameters and HI. However, use of ranks does not account for magnitude of differences.

When correlations between measurements are evaluated, data indicate that changes in HI estimates for the study ponds may account for up to 15 percent of the variability in richness (Table N5-6).

Sediment bioassay tests indicated toxicity only in sediments from Pond B-2 (Table N5-5). These results are also not consistent with toxicity predicted by HIs. The HI for Pond B-2 was the second lowest of the B-series. In addition, B-2 sediments contained lower concentrations of all sediment ECOCs and fewer PCOCs that exceeded sediment quality criteria than in Ponds B-1, B-3, or B-4.

Results of the analyses illustrate the conservative nature of the TRVs used in calculating HQs and HIs. In most cases, toxicity is overestimated. Results of toxicity tests and benthic community analysis do not reflect the high levels of toxicity indicated by HQs and HIs, especially in Ponds A-1 and B-1. Correlation of HI and community parameters ranks may be indicative of toxicity. However, the effects of robust differences in physical habitat may mask changes due to toxicity. Potential toxicity of sediment contaminants, particularly PAHs and silver, may be important factors in limiting aquatic communities if physical stress was reduced through a change in management of the ponds.

N5.1.2 Potential Impacts of Groundwater on Surface Water Quality

This section describes the potential impact that existing groundwater contamination may have on surface water quality at RFETS. Based on data available from RFI/RIs and sitewide groundwater and surface water sampling, a conceptual model was developed to qualitatively assess the potential for groundwater contamination to affect surface water quality at RFETS. Groundwater monitoring and investigations indicate that groundwater quality has been impacted in OU1, OU2, OU4, and OU5 (DOE 1993d, 1994f, 1995e, 1995f, EG&G 1994d) and the assessment focuses on sources in these areas (Figure 5-10). However, groundwater contamination in the IA/PA portion of RFETS is not yet characterized and, therefore, the potential effects of contaminants in this area cannot be assessed. A comprehensive evaluation of sitewide groundwater and movement contamination (including the IA) is planned. Results of this evaluation are needed to perform a quantitative evaluation of effects of groundwater on surface water quality at RFETS.

The level of risk associated with groundwater contamination is dependent on a complete pathway to a surface water body, the contaminant level in groundwater, and dilution of contaminated groundwater as it mixes with surface water. The assessment focuses on risks to aquatic life by comparing groundwater PCOC concentrations to Colorado state water quality standards. The evaluation was

qualitative and intended only to identify surface water bodies potentially at risk from contamination by groundwater. Various aspects of the hydrologic system were examined, including groundwater flowpaths to surface water bodies, surface water-groundwater interaction, and contaminant levels in groundwater.

Groundwater flowpaths were examined to determine if contaminated groundwater could reach a surface water body. The interaction between surface water and groundwater in stream drainages has only been studied along Woman Creek (DOE 1995f). Therefore, the results of this study are used to provide a general framework for groundwater-surface water interaction throughout the site.

N5.1.2.1 Risks from OU1 Groundwater

Groundwater in OU1 flows from the hilltop down the hillside toward Woman Creek. However, a complete groundwater to surface water pathway does not exist at OU1 because a French drain has been installed to intercept groundwater flowing down the OU1 hillside in the unconsolidated deposits (EG&G 1995b).

Groundwater also flows beneath the French drain in the underlying claystones and siltstones of the Laramie Formation. However, a downward hydraulic gradient exists between the unconsolidated materials and bedrock in almost all areas of the site (EG&G 1995b). Therefore, any contaminants in the weathered bedrock will probably not flow upward into the unconsolidated materials where they may contact surface water.

The existing French drain and hydraulic conditions at OU1 prevent contaminated groundwater from reaching Woman Creek. Thus, groundwater in OU1 does not appear to pose a risk to surface water quality.

N5.1.2.2 Risks from OU2 Groundwater

Most of OU2 is situated on an east-west-trending ridge bounded to the south by the Woman Creek drainage and to the north by South Walnut Creek. Groundwater flows along the length of the ridge in both unconsolidated deposits and bedrock sandstones. Seeps form along the hillsides in areas where bedrock sandstones subcrop or at the alluvium-bedrock contact. Groundwater from these seeps evaporates, is transpired by vegetation, or flows down the hillsides to South Walnut Creek or Woman Creek. Groundwater also flows within the unconsolidated materials down the hillsides toward South Walnut Creek and Woman Creek (DOE 1993d).

Groundwater in the valley-fill alluvium contributes water to the stream flow of Woman Creek only during the wettest months (December through April) (DOE

1995f). Although no studies have been performed to determine groundwater-surface water interaction along South Walnut Creek, it is assumed that the hydrology is analogous to that of Woman Creek. Thus, it is likely that South Walnut Creek is gaining only during the wettest months.

Groundwater in the bedrock beneath the streams will not flow upward into the valley-fill alluvium and then into the stream because a downward hydraulic gradient exists between the weathered bedrock and overlying alluvium in almost all areas of the site (EG&G 1995b).

As part of remedial investigations at OU2, water samples were collected from seeps. Contaminants in seep water that exceed the surface water standards for aquatic life include carbon tetrachloride and trichloroethene in seeps above the Walnut Creek drainage and only carbon tetrachloride in seeps facing the Woman Creek drainage. In addition, trichloroethene, manganese, antimony, and strontium exist at levels above the surface water standard in samples from groundwater flowing toward South Walnut Creek. In samples from groundwater flowing toward Woman Creek, chloroform, tetrachloroethene; 1,1-dichloroethene, manganese, antimony, and strontium are found at levels above the surface water standard (DOE 1993d).

N5.1.2.3 Risks from OU4 Groundwater

Groundwater in OU4 flows from the solar ponds northward to North Walnut Creek and southeastward to South Walnut Creek. Groundwater in the unconsolidated deposits north of the ponds is largely intercepted by the interceptor trench system (ITS). However, construction records indicate that the ITS is not keyed into bedrock at all locations. Groundwater, therefore, is able to flow beneath the ITS in the unconsolidated deposits toward North Walnut Creek.

Seeps are present on the hillside north of the solar ponds facing North Walnut Creek. Surface runoff from these seeps is intercepted by the southern extension of the ITS, which effectively collects all surface water flowing down the hillside. This water is then pumped to temporary storage tanks prior to treatment (DOE 1994f).

Groundwater also flows beneath the ITS in the underlying claystones and siltstones of the Laramie formation. As described above, a downward hydraulic gradient exists between the unconsolidated materials and bedrock in almost all areas of the site (EG&G 1995b). Thus, any contaminants in the weathered bedrock will not flow upward into the unconsolidated materials.

No site-specific studies have been performed to analyze the interaction between groundwater and surface water along either North Walnut Creek or South Walnut

Creek. However, it is assumed that the hydrology is analogous to that of Woman Creek. Thus, it is likely that both South Walnut Creek and North Walnut Creek gain only during the wettest months (December through April).

The most serious threat to surface water quality from OU4 groundwater appears to be from nitrate/nitrite. Elevated levels of nitrate/nitrite have been detected along North Walnut Creek and in the immediate vicinity of the ponds. Additionally, americium-241 and 1,1-dichloroethane are sporadically detected above the surface water standard at single locations near the solar ponds. The maximum concentrations/activities of nitrate/nitrite, americium-241, and 1,1-dichloroethane in unconsolidated deposits during 1993 are 850,000 µg/L, 5,764 pCi/L, and 52 µg/L (EG&G 1994d).

The americium-241 and 1,1-dichloroethane were each detected at levels exceeding the surface water standard only once in 1993. The elevated levels of americium-241 are anomalous. Activities in samples from the same location are two or three orders of magnitude lower during the rest of the year. Therefore, americium-241 is not considered to pose a risk to aquatic life in the OU4 area. The single detection of 1,1-dichloroethane (52 µg/L) is only slightly above the surface water standard (47 µg/L). The concentration of 1,1-dichloroethane will certainly decrease below the standard upon mixing with surface water. Therefore, 1,1-dichloroethane poses no significant risk to surface water in OU4 (EG&G 1994d).

Because a groundwater investigation has not been completed for OU4, the only available source of data is the Annual RCRA Groundwater Monitoring Reports. These reports contain primarily information on radionuclides, VOCs, and water quality parameters for OU4. No detailed information about dissolved metals was presented. Thus, the risk to aquatic life from dissolved metals in OU4 groundwater has not been assessed.

N5.1.2.4 Risks from OU5 Groundwater

Groundwater in OU5 flows from the hilltop through unconsolidated materials and landfill materials southward to the valley-fill alluvium along Woman Creek. Groundwater flows to the east in the valley-fill alluvium paralleling Woman Creek. Woman Creek is gaining only during the wettest months (December through April). Thus, groundwater flows into the stream only during this period. Groundwater discharges to the surface in areas of shallow bedrock as seeps and springs along the hillside. Water from these seeps and springs is transpired by vegetation, evaporates, or flows downhill where it is intercepted by the SID (DOE 1995f).

Groundwater in the bedrock also flows from the hilltop southward to Woman Creek. As stated above, groundwater in the bedrock does not recharge surface

water bodies at RFETS and, therefore, cannot contribute to degradation in surface water quality (EG&G 1995b).

Only two groundwater COCs in OU5 (aluminum and manganese) exceed the surface water standard for aquatic life. Both aluminum and manganese are present at levels above the surface water standard. Maximum concentrations of aluminum and manganese in OU5 groundwater are 4,900 µg/L and 10,500 µg/L, respectively (DOE 1995f).

N5.1.2.5 Risks from OU7 Groundwater

The groundwater system in OU7 is somewhat complex. The key components of the hydrologic system in OU7 are the landfill, landfill pond, groundwater-intercept system upgradient of the landfill, and the landfill pond dam. Most of the groundwater in the unconsolidated deposits is diverted around the landfill to the landfill pond by the groundwater-intercept system. Groundwater that flows through the landfill materials is discharged to the landfill pond (DOE 1995e).

Water from the pond infiltrates into the weathered bedrock and flows under the dam. However, the pond dam prevents most groundwater in the unconsolidated deposits from flowing downgradient toward No Name Gulch. As a result, the unconsolidated deposits downgradient of the dam are often unsaturated and many of the contaminants are trapped in the landfill pond.

No site-specific studies of groundwater-surface water interaction have been performed along the unnamed tributary to Walnut Creek (No Name Gulch). It is assumed that the hydrology is analogous to that of Woman Creek. Therefore, it is likely that No Name Gulch gains only during the wettest months (December through April).

Only groundwater quality downgradient of the dam is of concern because the pond and dam serve to limit the movement of contamination in groundwater. Furthermore, only contaminants in the unconsolidated deposits may pose a risk to surface water quality because a downward hydraulic gradient exists between the unconsolidated materials and underlying bedrock (DOE 1995e).

Comparisons of water quality data to the surface water standards indicate that only sulfate and fluoride are present in unconsolidated deposits at levels exceeding surface water standards. (No surface water standard for aquatic life for fluoride was available; therefore, the domestic use standard, 2,000 µg/L, was used for comparative purposes.) Fluoride concentrations in groundwater samples downgradient of the dam range from 400 to 79,221 µg/L. Sulfate concentrations in samples from unconsolidated materials groundwater downgradient of the dam range

from 33,000 to 770,000 µg/L (surface water standard for aquatic life standard is 250,000 µg/L) (DOE 1995e).

N5.1.2.6 Summary

Groundwater in several areas of RFETS has the potential to adversely affect surface water quality and may pose a risk to aquatic life. However, the risk associated with existing groundwater contamination is limited by several factors (Figure 5-10).

Groundwater flows into streams at RFETS only during the wettest months. Therefore, contaminant loading to the streams is limited to only part of the year.

Mixing of groundwater and surface water in the stream drainages dilutes contaminated groundwater, and the resulting concentrations in surface water will be lower. Furthermore, groundwater flow into streams occurs only during the wettest months when stream flow is highest and dilution is greatest. The resulting contaminant concentrations in surface water may then be below the surface water standards for aquatic life.

VOCs in groundwater will volatilize when exposed to the atmosphere. Thus, VOC concentrations will decrease as seep water flows toward surface water bodies or as groundwater mixes with surface water in the streams. The amount of volatilization is dependent on the properties of the analyte and length of the flow path.

N5.2 Aquatic-Feeding Birds

Chemicals identified as ECOCs for aquatic-feeding birds included DBP, mercury, and PCBs. Mallards and great blue herons were identified as representative species because they are relatively common at RFETS and because birds are generally more sensitive to organic contaminants than are mammals. Analyses used in the risk characterization were described in Section N4.3. The following subsections provide more detail on methods and present results. Because the analysis approach differed by chemical, results are presented separately for each ECOC.

N5.2.1 Risk from Aroclor-1254

As noted in Section N4.2, available data on concentrations of Aroclor-1254 indicate negligible risk to aquatic-feeding birds. However, further analyses were needed because (1) data on biological tissues were not available for all ponds in which PCBs were detected in sediments; and (2) development of the aquatic community in ponds could result in increased biological transport of sediment contaminants and increased exposure to aquatic-feeding birds.

Site-specific information was used to estimate the uptake of PCBs by fish and other aquatic life in ponds for which biological tissue data were not available. This approach was used because site-specific data were available and because use of EqP theory and BCFs to predict food web transfer overestimated tissue concentrations by at least one order of magnitude. For example, use of EqP and BCF to predict tissue concentrations in fathead minnows in Pond B-4 resulted in a concentration of 5.4 mg PCB/kg tissue, while the maximum concentration measured in fish taken from the pond was 0.48 mg/kg.

During RFI/RI field sampling at OU6, sediments were collected from multiple locations within each of the A- and B-series ponds and analyzed for several PCB congeners. Only Aroclor-1254 and Aroclor-1260 were detected in these samples, and concentrations varied considerably between ponds (Figure N5-11). The highest concentrations were in the most upstream ponds in each watershed, with progressively lower concentrations downgradient. In general, concentrations in sediments from the B-series ponds averaged ten times those in the A-series ponds, reflecting the fact that the South Walnut Creek watershed includes most of the industrialized area of RFETS and receives discharge from the wastewater treatment plant. PCBs were detected in 100 percent of the samples from Ponds A-1, B-1, B-2, B-3, and B-4; in three of four samples from Pond A-2; and in none of the samples from Ponds A-3, A-4, or B-5 (DOE 1994c).

Aquatic organisms typically are not exposed to sediments below the upper 15 cm. Data generated during the RFI/RI field program, which included collection of sediment samples below this depth, did not permit evaluation of biological exposures. Consequently, sediments and biota in the ponds were re-sampled and re-analyzed to obtain data more appropriate for assessing ecological risk. Samples were taken from the upper 15 cm at the same sites sampled during the earlier investigation. Where available, tissue samples were also collected for fish, salamanders, crayfish, and benthic macroinvertebrates. Sampling was conducted in June and July 1994. A preliminary report on the results of this follow-up sampling and analysis program was submitted to DOE by EG&G (Stiger 1994). The exposure analysis and risk characterization presented here was based on results of the 1994 sampling.

The following subsections present results of analyses described in Section N4.3. This information provides a basis for developing site-specific remediation criteria for protection of aquatic-feeding birds from toxic exposures to PCBs in pond sediments.

N5.2.1.1 Distribution of PCBs in Pond Sediments and Biota

Results of sediment sampling are presented in Table N5-7. As with the earlier sampling, PCB concentrations were higher in the B-ponds than in the A-ponds, with the highest concentrations in Pond B-2. However, the maximum concentrations were generally lower than in the earlier (RFI/RI) samples. As noted above, the earlier sampling program included collection of sediment from variable depths greater than the upper 15 cm to which aquatic organisms are typically exposed. The fact that sediments within the upper 15 cm had generally lower PCB concentrations than the deeper sediments suggests a lower risk to aquatic life than indicated by the earlier data.

Biota was sampled in all ponds. However, some of the ponds did not produce samples sufficient for analysis. Adequate samples were obtained only for Ponds A-2, A-3, A-4, B-1, B-2, B-4, and B-5 (Table N5-8). Limited availability of biota also resulted in samples of variable taxa among ponds. Taxa collected for analysis included largemouth bass from Pond A-2; fathead minnows from Ponds A-4, B-4, and B-5; tiger salamander larvae from Ponds B-1 and B-2; and crayfish from Ponds A-2, A-3, A-4, and B-5. A single sample of benthic macroinvertebrates was collected from Pond A-2.

Concentrations of Aroclor-1254 in aquatic biota ranged from below detection limit (BDL) to 500 mg/kg in a fathead minnow sample from Pond B-4 (Table N5-7). The highest concentrations in tissues were not detected in samples from the ponds with the highest sediment concentrations. Aroclor-1254 was not detected in any of the crayfish samples. However, with the exception of Pond A-2, crayfish were captured in ponds with one (Pond A-3) or no sediment samples with detectable PCBs in sediments.

The ratio of Aroclor-1254 content in biota to that in sediments was calculated for ponds in which Aroclor-1254 was detected in both sediments and biological samples (Table N5-9). The variability of biota types available, and the lack of PCB detections in some ponds with biota, limited comparison of BSF values among ponds. BSF ratios varied among biota types, ranging from 0.1 in salamander neonates from Pond B-1 to 3.3 in fathead minnows from Pond B-4. Largemouth bass, which were found in only in Pond A-2, had a BSF of 0.6. These values are comparable to BSFs estimated for aquatic biota in other studies (Rasmussen *et al.* 1990, Macdonald *et al.* 1993).

The relationship of food chain length and BSF was also difficult to evaluate because of the inconsistent presence of aquatic species in the ponds. However, bioaccumulation effects may explain results for Pond A-2, where the BSF for bass

was approximately twice that for benthic macroinvertebrates. The latter were probably the main prey of bass in this pond, because fathead minnows and salamander larvae were apparently absent.

N5.2.1.2 Evaluation of Potential Risk and Development of Remediation Criteria

Risk of PCB toxicity to herons and mallards from ingestion of toxic levels of PCBs was evaluated first using available data on PCB concentrations in fish and macroinvertebrate tissue (Section N3). The screen indicated negligible risk. However, available biological tissue data may not represent all possible exposure scenarios and do not provide location-specific evaluations.

Potential risk was further evaluated using site-specific data on biological uptake of PCBs to estimate protective concentrations in sediments, called EECs, that would result in exposures equal to or less than the TRVs. Available data for pond sediments were then compared to the EECs. EECs were developed for use as guides in developing remediation criteria. The EECs vary with the intensity of site use and complexity of food chains (Table N5-10). The most restrictive EECs are associated with the highest level of site use and longest food chain.

When EECs were compared to current concentrations of Aroclor-1254 in sediments at RFETS, risk was identified only for the most restrictive scenario, great blue herons feeding in ponds with piscivorous fish present (Table N5-10, Figure N5-12). For all ponds, the maximum concentrations of Aroclor-1254 in sediments were below criteria derived for 100-percent site use by mallards (Table N5-10) and great blue herons feeding in ponds without piscivorous fish (Figure N5-13A).

For longer food chains, the evaluation indicated potential risk for herons feeding in Ponds B-1, B-2, and B-3 (Figure N5-13B). For example, maximum Aroclor-1254 concentration exceeded EECs for site use greater than 20 percent in Pond B-2 and 30 percent in Ponds B-1 and B-3 (Figure N5-13B). Mean Aroclor-1254 concentrations exceeded the EECs for 40 percent site use in Pond B-2, 70 percent in Pond B-1, and 90 percent in Pond B-3 (Figure N5-13B).

Using maximum Aroclor-1254 sediment concentrations for comparison, it appears that mallards and herons would not experience a toxic exposure from sediment PCB contamination by feeding on invertebrates or forage fish in any of the ponds. The data also suggest that a heron feeding in the most contaminated pond (B-2) would not experience a toxic exposure from PCBs unless more than 20 percent of its diet was composed of piscivorous fish from there. When mean sediment concentrations were used for comparison, the results indicate that the exposure in Pond B-2 would probably not exceed the TRV for herons unless site use was

greater than about 45 percent and they fed exclusively on upper-level aquatic predators.

Aroclor-1254 was also identified as an ECOC in the 903 Pad ERA source area, primarily due to concentrations detected in sediments in the SID. The initial risk calculations were based on estimates of PCB uptake by aquatic biota, because no tissue data were available for the site. The uptakes were based on potential bioconcentration of PCBs from interstitial water. Data on total organic carbon in sediment from the SID were not available. However, the maximum Aroclor-1254 concentration detected in bulk sediments (0.26 mg/kg) was below the average concentrations in Pond A-3, which appeared to represent negligible risk to aquatic-feeding birds.

Results of this analysis suggest that piscivorous birds would be most at risk from PCB toxicity if they fed exclusively in Ponds B-1, B-2, and B-3. This scenario seems unlikely, because none of these ponds currently supports extensive fish populations. In addition, the uptake calculations may overestimate PCB concentrations in fish because the maximum BSF (3.3) found in site data was used. The next highest BSF, less than one-third of this value, was calculated for largemouth bass, which is the highest-level aquatic predator found at the site.

In addition to assessing risks of PCB toxicity, the results of this analysis can be used as a guide for developing remediation criteria for protection of aquatic-feeding birds or in evaluating the protectiveness of remedial criteria developed for other purposes.

N5.2.2 Risk from Mercury

Mercury was identified as an ECOC in the B-Ponds, C-Ponds, and Old Landfill source areas. In each source area, mercury was included as an ECOC because of measured or calculated concentrations in fish tissues.

The C-Ponds and Old Landfill are located in the Woman Creek watershed and included in OU5. Mercury was identified as a PCOC in soil, groundwater, stream sediments, and pond sediments in OU5 (Table N5-11A). The Old Landfill is immediately upstream of the C-Ponds source area and could be a source of contaminants to downstream areas, including the C-ponds.

Mercury was detected in 2 of 13 (15 percent) fish collected from Pond C-1 (Table N5-11A). The maximum detected concentration (0.47 mg/kg) was greater than the average dietary concentration (0.027 mg/kg) considered safe for great blue herons (Opresko *et al.* 1994) and corresponds to an HQ of 17. Mercury was identified as

an ECOC for the Old Landfill source area based on the estimated bioconcentration in fish tissue calculated from the maximum detected concentration in surface water.

Mercury was detected in less than 50 percent of samples from all media in OU5 except pond sediments (Table N5-11A). Therefore, pond sediments are probably the primary source for uptake of mercury by fish in Pond C-1. However only 15 percent of fish collected from Pond C-1 contain detectable quantities of mercury. Moreover, it is possible that the two samples with detectable quantities may have had sediment in the gastrointestinal tract when analyzed.

Actual risks to great blue herons from mercury ingestion are probably less than indicated by the HQ of 17, because this value was calculated using the maximum detected mercury concentration in fish and assuming that the herons obtain all of their food from Pond C-1. Great blue herons do return frequently to feeding areas, but they could not use a pond the size of C-1 exclusively. Thus, the risk estimate probably overestimates both the exposure-point concentration and the frequency of exposure.

Two-thirds of fish from the B-series ponds contained detectable levels of mercury (Table N5-11B). However, mercury was not identified as a PCOC for pond sediments or surface water in OU6. It was identified as a PCOC for soils, groundwater, and stream sediments in OU6 (Table N5-11B). The highest concentrations in fish were detected for Pond B-5, the terminal pond in the series and the one that generally had the lowest concentrations of OU6 PCOCs. Thus, the source of mercury in fish is unclear. The maximum concentration in fish from the B-Ponds was much less than that found in fish from Pond C-1 and corresponds to an HQ of 2 when compared to the dietary levels noted above.

N5.2.3 Risk from Di-N-butyl phthalate

DBP was identified as an ECOC for aquatic-feeding birds based on estimated bioconcentration from surface water. DBP was detected in six surface water samples from Ponds A-2, A-3, and B-4. However, the following evidence suggests that DBP may not be a persistent contaminant or represent unacceptable risk in the ponds:

- The maximum concentration detected in surface water was 2 µg/L, and all six of the detectable quantities were estimated below the CRDL of 10 µg/L (i.e., result was "J"-qualified).
- DBP is a hydrophobic compound ($\log K_{ow} = 4.57$) and would probably accumulate in the organic fraction of sediments if persistently present. However, DBP was not detected in sediments from any of these ponds.

- DBP is a common laboratory contaminant.
- The magnitude of the estimated exposures may be overly conservative. The risk estimate was based on an HQ of 2, which was calculated from the maximum DBP concentration in surface water (2 µg/L). This concentration was detected only in Pond A-3. All other detectable concentrations were 1 µg/L, which corresponds to an HQ of 1, suggesting minimal risk. The exposure estimate also assumes that aquatic-feeding birds spend all of their time feeding in areas of maximum contamination. Thus, the HQ for DBP exceeds 1 in only one of the nine ponds in the upper Walnut Creek watershed.

N5.2.4 Risks from Antimony

Antimony was identified as an ECOC based on incidental ingestion of sediments from Woman Creek. The HQ of 1.6 was based on 100-percent site use by herons in the section of Woman Creek in the Old Landfill source area. This segment of Woman Creek is seasonally intermittent and supports a minimal fish population. Herons have not been observed in this area, although they have been sighted at Pond C-1. It is unlikely that a heron would use this segment of Woman Creek to the extent necessary to exceed an HQ of 1.

N5.3 Terrestrial-Feeding Raptors

As noted in Section N4.3, chromium, lead, mercury, and vanadium were detected in terrestrial arthropods from OU2 and small mammals from OU4 and OU6 source areas (OU4/6 area) at concentrations that could be toxic to raptors feeding extensively in the areas. American kestrels were selected to represent ecological receptors because they have relatively small home ranges and are known to breed at RFETS.

The objective of the risk characterization was to refine the exposure estimates to assess whether or not individual birds feeding in the area would experience exposures that exceed the TRVs and, if so, identify contaminated areas that contribute most to the risk. This was accomplished by (1) reviewing information on contaminant distribution to determine the spatial extent of contamination and representativeness of data, and/or (2) estimating the probability that an individual bird feeding in the area would experience a toxic exposure.

N5.3.1 Risk from Chromium in Terrestrial Arthropods from OU2

Ecotoxicological risks (HQs) for chromium exposure to American kestrels in the OU2 source areas were primarily due to concentrations of chromium in terrestrial arthropods (TAs) in OU2 source areas. The risk estimate is based on exposure to chromium III because this is the most common form at RFETS (Lewis 1995).

Evaluation of the TA data indicates that chromium was detected in three of five TA samples collected from OU2 source areas (Table N5-12A and Figure N5-14). Only one of these samples exceeded the CRDL (74.9 mg/kg at MG07A2) (Table N5-12A). The exposure-point concentration for the OU2 East Trenches source area is the UCL₉₅ of chromium in TAs from the OU2 East Trenches source area. Thus, this exposure-point concentration is heavily influenced by a maximum concentration that was more than 30 times greater than the next highest concentration (2.3 mg/kg). As a result, the risk estimate for chromium in the OU2 East Trenches source area is based primarily on one sample that appears to have an anomalously high concentration.

Because adequate TA samples were not available, chromium exposure-point concentrations for the OU2 903 Pad source area and the OU2 Mound source area were estimated from the ratio of chromium in TAs to chromium in surficial soil for the OU2 East Trenches source area. Thus, risk in the OU2 903 Pad and OU2 Mound Area source areas may also be based on an anomalous measurement. If the maximum TA chromium concentration were treated as an outlier and excluded from the calculations of the exposure-point concentrations, the HQ for chromium exposure to American kestrels would be well below 1.

Although chromium was included in the list of PCOCs for OU2, samples from only 2 of 24 surficial soil sampling locations within OU2 had concentrations above the UTL_{99/99} for surficial soil in RFETS background (16.6 mg/kg) (Table N5-12B) (DOE 1994d). Both of these sampling locations are in the OU2 903 Pad source area. No surficial soil samples in the OU2 East Trenches source area or the OU2 Mound source area exceeded the RFETS background UTL_{99/99}. In addition, samples from only 3 of the 24 sampling locations within OU2 exceeded the RFETS background mean of 15.3 mg/kg. Moreover, because the OU2 903 Pad source area includes portions of OU1, the OU2 903 Pad source area exposure-point concentration was calculated using samples from 9 locations within OU1, including a sample from a site in OU1 IHSS 119.2 that had a value of 80.5 mg/kg (Table N5-12A). Therefore, the risk estimate for exposure to kestrels to chromium in the OU2 903 Pad source area is based in part on sample concentrations from OU1 that are not due to OU2 sources.

The total area of the OU2 source areas (69.2 ha) represents less than twice the home range of an American kestrel (38 ha) (DOE 1995a). Because the OU2 source areas represent 2.6 percent of the total area at RFETS, only a small proportion of the American kestrel population at RFETS is likely to be exposed to the chromium in terrestrial arthropods in OU2.

N5.3.2 Risks from Chromium, Lead, Mercury, and Vanadium in Small Mammals

N5.3.2.1 *Distribution of ECOCs in Soils, Sediments, and Small Mammals*

Soils and Sediments

Chromium, lead, mercury, and vanadium were identified as ECOCs in soil in OU6. Mercury was also identified as an ECOC in OU4. Contamination of surface and subsurface soils in OU6 and OU4 was of relatively low magnitude. Mean concentrations of chromium, lead, and vanadium in surface and subsurface soils were not greater than concentrations in background soils, and 2 percent or less of the samples exceeded the UTL_{99/99} of the background mean (Table N5-13)(DOE 1994e). The mean mercury concentration in surface soils exceeded the background mean, but the detection frequency was only 41 percent, and none of the samples from OU6 exceeded the background UTL_{99/99} (Table N5-13).

Sediments of the A- and B-series ponds contained all four metals. However, mean concentrations in dry (not inundated) sediments were not greater than in OU6 or background surface soils, and none of the samples contained metals above the background UTL_{99/99}.

Small Mammals

Chromium and lead concentrations in small mammals were higher in the OU4/6 area than in the background areas (Table N5-14, Figure N5-15). The elevated metals concentrations were due primarily to samples taken from the A-Ponds and B-Ponds source areas. Small mammal samples from the OU4 Downgradient and OU6 Soil Dump source areas did not contain elevated concentrations of these metals.

Mercury and vanadium were also higher in animals from OU4 and OU6 than those from background areas. Neither metal was detected in background samples. However, detection frequencies were also low for samples from OU4/6 area.

N5.3.2.2 *Probabilistic Exposure Estimates*

In order to better estimate risk to kestrels from ECOCs in the OU4/6 area, ingestion of chromium and lead in small mammals was simulated using Latin hypercube procedures to estimate the distribution of exposures expected in the field (Iman and Conover 1980, Bartell *et al.* 1992, Suter 1993). Data on chromium and lead concentrations in small mammals were used to estimate the (statistical) distribution of the exposure-point concentrations. Frequency histograms indicated a lognormal distributions for both metals (Figure N5-16). The empirical distributions from site

data were not used because data sets were relatively small and therefore probably do not represent the true distribution (Bartell *et al.* 1992, Kirchner 1993).

Concentrations were then [pseudo-]randomly sampled from the data distributions using stratified random, or Latin hypercube, procedures; these concentrations were then used in the exposure calculation (Bartell *et al.* 1992). This process was repeated 500 times, resulting in 500 exposure estimations from which a mean and standard deviation could be calculated. The results were also used to construct a probability density function (pdf) that was used to estimate the probability of exceeding certain critical values (i.e., TRVs). This approach allowed propagation of the uncertainty associated with the input parameters and estimation of the probability that kestrels will experience a potentially harmful exposure.

Results of simulations are presented in Table N5-15 and Figure N5-17. Estimated ingestion of both chromium and lead was greater for the OU4/6 area than background (Figure N5-17). Based on simulated ingestion rates, kestrels feeding on small mammals in the OU4/6 area have about a 63 percent chance of exceeding the TRV for chromium and a 50 percent chance of exceeding the TRV for lead (Table N5-15). Kestrels feeding in background areas of RFETS have about a 23 percent chance of exceeding the chromium TRV but are not likely to exceed the lead TRV (Table N5-15).

These results suggest that kestrels feeding exclusively in the OU4/6 area of Walnut Creek may experience toxic exposures to chromium and lead. The total area of the source areas included in the analysis is about 28 ha, or about 75 percent of the normal foraging range of kestrels in Front Range (38 ha) (DOE 1995a). Thus, this estimate may be relatively representative of kestrels in the wild since they were assumed to spend all of their time in the OU4/6 area.

The exposure estimate assumes that all of the chromium and lead in the small mammals was bioavailable and absorbed by the kestrels. This conservative assumption was made because it is difficult to assess the actual bioavailability. However, it is likely that at least some of the metal content in tissue was due to soil or sediment particles adsorbed to external body surfaces or contained within the gastrointestinal tract. Chromium and lead in soil particles is probably less bioavailable than solubilized or organically transformed metals contained in tissues.

Review of the small mammal tissue data indicates that animals captured near the ponds contribute most to the kestrel exposure estimate (Table N5-14, Figure N5-15). However, the source of chromium and lead in the small mammals is unclear. Data for dry sediments do not indicate elevated concentrations in surface materials around the ponds. Chromium and lead may be more available to small mammals in

these areas because of the fine texture of the sediment compared to surface soils in more upland areas. Finer materials would result in more adsorption to surfaces and higher bioavailability of metals in ingested soils. In any case, it appears that if the source of chromium and lead to small mammals around the ponds were attenuated, uptake of these metals by kestrels would be near background levels.

N5.4 Small Mammals

Small mammals were identified as a key ecological resource because of their importance as a prey base for many vertebrate predators and because of the presence of PMJM, a rare subspecies listed as Category 2 by the USFWS. Small mammals also represent a limiting exposure scenario because of their small home ranges and relatively constant and intimate contact with surface and subsurface soils.

Barium, selenium, and toluene were identified as ECOCs for small mammals. Barium and selenium were present at potentially toxic concentrations in vegetation in the North Spray Field and OU7 Downgradient source areas. Toluene was identified as potentially toxic in air of burrows in the 903 Pad and East Trenches source areas in OU2. As noted in Section N3, subsurface soils in these areas also contained organic PCOCs for which no inhalation TRVs were available. Risk from the ECOCs and less well characterized PCOCs is discussed below.

N5.4.1 Risk from Barium

Barium was detected in vegetation samples from the North Spray Field at concentrations that could be toxic to herbivorous small mammals. Barium was identified as a PCOC in subsurface soil and groundwater in OU6 (DOE 1994e). The North Spray Field source area includes areas identified as probable habitat for the PMJM (Figure N3-7). Therefore, risk to individual animals should be considered in risk management decisions.

The TRV for barium was based on concentrations that produced hypertension in laboratory rats (Perry *et al.* 1983 as cited in Opresko *et al.* 1994). The concentration on which the NOAEL was based was the maximum dose in the study and did not affect growth or food or water consumption experimental animals. Therefore, the level of risk associated with exceeding the TRV is unclear. The HQ for barium in the North Spray Field was 1.05 indicating exposures approximately equal to the NOAEL. Thus, the barium concentration in vegetation in this source area may produce some adverse effects in individual animals, but the potential for long-term effects on growth or reproduction is unclear.

N5.4.2 Risk from Selenium

Selenium was also detected in vegetation at concentrations that could exceed the TRV for ingestion by small mammals. Selenium was identified as an ECOC in the OU7 Downgradient areas (Figure N3-20). Selenium was detected in surface soils of OU7 at concentrations that exceed background levels (DOE 1995e). The HQ for selenium was 2.4.

The TRV was based on intakes calculated for background areas of RFETS (0.317 mg/kg/day) because it exceeded the literature-based ecotoxicological benchmark (0.075 mg/kg/day). The estimated background intake was about three times the minimum intake needed for maintenance in pregnant rats (NRC 1995). The intakes estimated for background areas and the OU7 Downgradient area were based on total selenium in food and incidentally ingested soils. Inorganic forms of selenium may be less bioavailable and therefore, site intakes may overestimate the amounts absorbed through intestinal walls. Small mammals inhabiting RFETS may be adapted to high ambient concentrations of selenium that are common in semi-arid areas of the Rocky Mountain west. However, intakes from the OU7 area are more than twice those estimated for background areas and may represent a risk to individuals that spend all of their time there.

The source of selenium in vegetation from the OU7 downgradient area is not clear. This area was not subject to spray evaporation of pond water (DOE 1995e). However, an area of groundwater with elevated selenium was identified during the OU7 RFI/RI (DOE 1995e). The highest concentration (7,200 µg/L) were found near the western end of the landfill pond, but the area of elevated concentrations extends eastward into the OU7 Downgradient source area. In addition, the vegetation samples from the area may have included selenium accumulators (such as *Astragalus* sp.) that are common at RFETS.

The area represents an insignificant proportion of the total mesic grassland habitat RFETS. The source area is located within areas identified as probable habitat for PMJM. Further sampling of vegetation and soils may be required to more fully characterize the risk of selenium to small mammals in this area.

N5.4.3 Risks from Toluene and Other Burrow-Air Constituents

Toluene exceeded the EEC for exposure of small mammals to burrow air in areas of OU2 that are known to contain buried waste or contaminated soil (Table N5-16, Figure N5-18). Inhalation TRVs were available for only six other organic PCOCs (Attachment 6, Table 9); soil concentrations for these compounds did not exceed TRVs. At the time this report was prepared, adequate information on respiratory toxicity was not available for most of the organic PCOCs found in soils, and

inhalation TRVs could not be set. Review of existing information in IRIS (EPA 1995b) indicates that EPA is currently developing reference concentrations (RfCs) for some of the compounds. Respiratory exposures were estimated for all organic PCOCs; these are presented in Attachment 6, Table 9.

Toluene irritates mucosal membranes of the eyes and respiratory tract at very low concentrations (EPA 1995b). Therefore, animals may avoid areas of contaminated soil when constructing burrows, fortuitously reducing their exposure. However, for purposes of this study, no avoidance behavior is assumed and all areas exceeding the EEC are included in Figure N5-18.

Areas in which toluene exceeded the EEC were identified using Thiessen polygons. These areas covered approximately 0.31 ha in the 903 Pad areas and 0.27 ha in the East Trenches area. All of the affected polygons lie within or adjacent to IHSSs (Figure N5-18). This result suggests that risks to burrowing animals from toluene exposure in OU2 may be restricted to the primary contaminant source areas. However, risk from organic PCOCs without TRVs remains unclear.

Areas impacted by toluene are found in the mesic and xeric mixed grassland habitat types on the ridge between South Walnut Creek and Woman Creek (Figure N5-18). None of the areas overlaps with probable PMJM habitat (Figure N5-18). The Thiessen polygons represent about 0.011 percent of the mesic and 0.088 percent of the xeric grassland habitat types at RFETS. These percentages may be used as a rough estimate of the proportion of burrowing habitat affected for more common species such as deer mice and prairie voles that use the drier, more upland areas of the site.

N5.5 Vegetation Communities

Results of the Tier 3 screen indicated several PCOCs exceed subsurface soil or sediment TRVs in several source areas (Table N3-23). This group of chemicals included mostly metals. Concentrations of organic PCOCs did not exceed TRVs (Attachment 6, Table 1). However, TRVs were not available for several organic compounds that were PCOCs for subsurface soil and sediments (Attachment 6, Tables 2 and 7). Subsurface soil data were not available for the OU5 Surface Disturbance, OU6 B-Ponds, or the OU10 Outside Closures. No HQs exceeded 1 for PCOCs in OU1 881 Hillside, OU2 East Trenches, and OU11 West Spray Field.

The highest HQ for exposure to subsurface soils was for nitrates (HQ = 170) in the OU7 Downgradient source area (Table N3-23). The source of nitrates in subsurface soils may be related to local groundwater contamination identified in the OU7 RFI/RI (DOE 1995e). Nitrate concentrations as high as 200 mg/L were detected in the area. However, detection frequency for nitrate in the OU7 Downgradient source

area was low indicating heterogenous distribution (Table N5-7). However, vegetation in the area does not show obvious signs of ecotoxic stress. Nitrate concentrations also exceeded the TRV (HQ = 4.8) in the OU4 Downgradient areas (Table N3-23). Nitrate concentrations in this source area are probably associated with a plume of contaminated groundwater originating in the OU4 Solar Pond area.

Chromium (7.9) nickel (3.7), and zinc (3.0) all had HQs of 3 or greater in the Ash Pits source area (Table N3-23). All other HQs for metals in subsurface soil were 2 or below.

Many of the TRVs for metals were equal to RFETS background soil concentrations, because literature-based toxicity values were below the UCL95 for background. Thus, HQs greater than 1 indicate concentrations that exceed background. Soil toxicity tests were not conducted using site soils. However, the risk associated with HQ values near 1 is unclear because background concentrations can vary by orders of magnitude. As noted previously, areas of obvious vegetation stress were not observed during preliminary field surveys. Thus, the importance of these risk estimates is not clear.

The potential phytotoxicity of sediments was also assessed as an indicator of potential effects on wetlands or the establishment of them. As with soils, TRVs were not available for many organic PCOCs. Sediment metal concentrations exceeded TRVs in at least one location for antimony, chromium, mercury, silver, vanadium and zinc. All HQs were below 10 except for silver in the B-Ponds. The highest silver HQ was 88 in Pond B-1 and progressively decreased in ponds downstream (Table N3-23). This pattern suggests a source of silver upstream of Pond B-1. The source could be related to the waste water treatment plant which formerly emptied to Pond B-1. The HQ of 88 suggests a high level of toxicity to aquatic plants. However, this HQ may overestimate risk, because Pond B-1 supports a vigorous plant community.

N5.6 Effects of Radionuclides on Plants and Wildlife

Transuranic radionuclides were elevated in soils and sediments and identified as PCOCs in most source areas. Concentrations (activities) at four locations exceeded the TRVs for radionuclides in soils (Higley and Kuperman 1995). Two of the locations were in the Old Landfill source area; samples from one exceeded the TRV for uranium-233/244 and uranium-238, while samples from the other exceeded only the TRV for uranium-238 (Attachment 6, Table 10 and Figure N5-20). The TRV for plutonium-239/240 was exceeded at two locations in the 903 Pad source area (Attachment 6 tables). These locations apparently represent very localized areas of

contamination and risk, because adjacent sampling locations did not contain radionuclides at concentrations that exceeded the TRVs.

Biological samples collected during field investigations also were analyzed for radionuclides. Concentrations of americium-241, plutonium-239/240, uranium 233/244, and uranium-238 in small mammals (Figure N5-21) and vegetation (Figure N5-22) were slightly to significantly elevated over samples collected from background areas.

The relationship between radionuclide content of soils and biota was variable. Maximum concentrations of americium-241 and plutonium-239/240 in vegetation and small mammals were found in samples from the source areas with the highest concentrations in soils. This was not the case for the uranium isotopes in either small mammals or vegetation. The relationship between radionuclide concentrations in small mammals and soils was evaluated for 11 source areas for which both data types were available (Table N5-18, Figure 5-23). Concentrations of plutonium and americium in small mammal tissue samples were well correlated with concentrations in soils, but concentrations of uranium isotopes were not. This result may reflect the higher aqueous solubility of uranium compounds. Plutonium and americium are tightly bound to clay and other particles in surface soils and tend to remain in surface materials. Uranium deposited on surface soils may be transported into deeper soils that are less accessible to small mammals at the surface.

The radiation dose resulting from the maximum concentrations of radionuclides in tissues from small mammals was assessed (Table N5-19). Results suggest that radionuclide concentrations are not a hazard to small mammals. Dose rates from individual radionuclides and the total radiological dose rate were at least 10,000 times less than the critical dose rate of 0.1 rad/day.

Tissue data were not available for species in higher trophic levels. Therefore, the total body burden for aquatic and terrestrial predators was estimated based on an assumed three-year exposure to radionuclide concentrations measured in small mammals and fish from RFETS. Body burdens were calculated using biological half-life values obtained from the literature (Table 5-19) (Killough and McKay 1976). The predicted body burdens for aquatic (Table N5-20) and terrestrial (Table N5-21) predators were at least 1,000 times less than the tissue concentrations required for the critical dose.

Although some radionuclide contamination was apparent at RFETS, the levels in soils and biological tissues do not appear to threaten ecological receptors. The levels of external and internal exposures presented in this study agree with the

previous study conducted at RFETS by Little *et al.* (1980) and other studies in the western United States (e.g., Hakonson 1975, Bly and Whicker 1978). The doses shown above are probably overestimates of the amount of radionuclides actually internalized and from which effective dose is received. Other studies indicate that greater than 90 percent of the plutonium associated with small mammals either adheres to the pelt or is contained in the gastrointestinal tract (Hakonson 1975). Because of the radiation stopping power of intestinal contents, less than 1 percent of the available alpha particle dose is actually applied to the intestine wall (Killough and McKay 1976). Less than one-half of gamma and beta emissions actually reach the intestinal wall.

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CHAPTER N5

TABLES

Table N5-1
Aquatic Life Sample Site Physicochemical Characteristics

Parameter	Units	Pond A-1	Pond A-2	Pond A-3	Pond A-4	Pond A-5	Pond B-1	Pond B-2	Pond B-3	Pond B-4	Pond B-5	Pond C-1	Pond C-2	Pond D-1	Pond D-2
Sample Date		6/3/94	5/27/94	6/17/94	7/1/94	6/23/94	6/27/94	6/23/94	6/13/94	6/7/94	6/9/94	6/17/94	6/13/94		
Total Volume ¹	10 ⁶ L	6.3	25.4	53.4	11.7	NA	3.0	7.3	2.4	2.3	87.6	NA	NA	NA	NA
Shoreline Length ¹	meters	297.5	419.8	629.2	853.3	378.15	158.7	307.9	210.6	171.6	615.6	266.32	762.37	485.5	619.76
Surface Area ¹	hectares	0.37	0.57	1.14	1.09	0.144	0.11	0.31	0.17	0.11	0.87	0.316	1.56	1.259	2.421
Max. Depth	meters	0.15	2.43	3.80	5.78	4.20	0.46	1.98	0.79	0.91	5.17	3.1	7.2	NA	NA
Water Temp.	°Celsius	29.6	20.1	24.6	25.0	18.8	32.6	29.5	25.8	28.1	24.1	16.8	19.98	NA	NA
Dissolved Oxygen	mg/L	8.8	6.2	7.0	8.2	6.9	6.9	7.3	8	8.2	7.3	5.0	6.07	NA	NA
Dissolved Oxygen	% saturation	141	83	102	121	ND	116	117	117	128	105	ND	ND	NA	NA
Conductivity	siemens	0.46	1.41	0.72	0.56	0.633	1.29	0.74	0.47	0.57	0.54	0.51	0.644	NA	NA
pH	standard unit	10.36	8.02	6.86	8.21	7.5	10.6	10.3	7.26	8.42	8.2	7.0	8.08	NA	NA
Alkalinity ²	mg/L	65	306	143	194	ND	230	304	81	112	133	ND	153	NA	NA

¹Maximum value based on high water level

²Total alkalinity as mg/L CaCO₃

mg/L - milligrams per liter

NA - data not available

ND - not determined

Table N5-2
Contribution of PAH to Sediments Hazard Index

Pond	Hazard Index	PAH Hazard Quotient	Contribution of PAHs to Hazard Index (%)
A-1	155.0	142.2	91.7
A-2	17.0	3.9	22.9
A-3	59.0	47.4	80.3
A-4	13.0	0.0	0.0
A-5	16.0	0.0	0.0
North Walnut Creek	181.0	154.0	85.1
B-1	1,996.0	1,867.2	93.5
B-2	74.0	7.7	10.4
B-3	134.0	50.0	37.3
B-4	251.0	220.1	87.7
B-5	8.1	0.0	0.0
South Walnut Creek	225.0	197.5	87.8
C-1	3.0	0.0	0.0
C-2	2.6	0.0	0.0
Woman Creek	1.2	0.0	0.0

Table N5-3
Pond Benthos Community Structure Summary

Characteristic	Pond A-1	Pond A-2	Pond A-3	Pond A-4	Pond A-5	Pond B-1	Pond B-2	Pond B-3	Pond B-4	Pond B-5	Pond C-1	Pond C-2	Pond D-1	Pond D-2
Total Richness	48	24	27	7	19	36	35	12	20	17	6	18	13	31
Mean Density	25,256.6	10,354.7	30,557.4	8,509.8	4,960.0	17,591.3	11,145.2	55,047.4	32,415.2	26,919.6	66.4	117.6	24,762.9	4,962.0
Simpson's Diversity	0.65	0.43	0.75	0.57	0.19	0.16	0.16	0.84	0.44	0.44	0.44	0.22	0.75	0.1
Shannon-Weiner Diversity	1.07	1.39	0.53	0.81	2.1	2.35	2.22	0.32	1.04	1.16	1.11	1.95	0.51	2.73
Shannon-Weiner Max. ¹	3.87	3.17	3.29	1.94	2.94	3.58	3.55	2.48	2.99	2.83	1.79	2.89	2.56	3.43
Percent Max. Diversity	27.65	43.85	16.11	41.75	71.43	65.64	62.54	12.90	34.78	40.99	62.01	67.47	19.92	79.59
Number Dominant Taxa	2.9	4	1.7	2.2	7.5	10.5	9.2	1.4	2.8	3.2	3	7	1.7	15.4
Dominant Taxa Density	21,917.7	9,120.4	29,790.8	7,951.2	4,544.0	15,863.4	10,172.9	49,538.8	31,388.8	21,592.8	61.6	105.4	24,204.2	4,482.1
% Density Dominant Taxa	86.7	88.1	97.5	93.4	91.6	90.1	91.3	89.9	96.8	80.2	92.7	89.6	97.7	90.3
Oligochaeta Density	20,241.7	1,676.0	26,257.0	6,145.3	1,720.0	5,014.9	194.9	4,586.2	17,455.0	16,837.7	41.6	42.0	21,255.0	39.0
% Density Oligochaeta	80.1	16.2	85.9	72.2	34.6	28.5	1.8	8.3	55.3	62.5	62.6	35.7	85.8	8
Diptera Density	3,167.8	8,367.1	4,066.5	1,974.9	2,552.0	1,232.5	3,339.0	571.7	12,263.6	5,105.9	24.8	68.4	3,422.1	3,001.1
% Density Diptera	12.5	80.8	13.3	23.2	51.4	7	30	1	37.8	19	37.4	58.1	13.8	60.4

¹Maximum Shannon-Weiner Diversity based on richness

Table N5-4

Tolerance Values and Densities for Most Common Taxa in Detention Ponds (organism density in number/m³)

Taxa	TV	Pond A-1	Pond A-2	Pond A-3	Pond A-4	Pond A-5	Pond B-1	Pond B-2	Pond B-3	Pond B-4	Pond B-5	Pond C-1	Pond C-2	Pond D-1	Pond D-2
Number of Dominant Taxa		3	4	2	2	7	11	9	1	3	3	3	7	2	15
Oligochaeta	5	20,242	1,676	26,257	6,145	1,720	5,015	195		17,955	16,838	42	42	21,255	
Diptera	7						546								
Chaoborus	7		598					559					7		
Chironomidae pupae	6					96									
Chironomus	10					704									
Cladopelma	7		6,548	3,534	1,806	312		2,365		11,563			33	2,949	1,104
Cladotanytarsus	7					816									
Corynoneura	7	845													
Cryptochironomus	8					272									
Dicrontendipes	8												2		377
Glyptotendipes	7														156
Labrundinia	7														104
Paratanytarsus	6														130
Procladius	9		299									13	6		78
Psectrocladius	8	832													598
Pseudochironomus	5														195
Tanytarsus	7											7	10		
phemeroptera	6						338								
Baetis	5						559								
Caenis	7														
Odonata	9						1,351	533							312
Coenagrion/Enallagma	9														91
Hemiptera	unk.												6		286
Corixidae															
Coleoptera	7						507	234							
Haliphus															
Crustacea															
Cladocera	8						377	299			1,962				117
Ostracoda	8						2,079	2,546	49,539	1,871	2,793				
Malacostraca															
Hyalella	8						780	1,117							117
Gastropoda															
Gyraulid	8														
Physella	8						3,820	2,326							312
Limnophila	8						494								507
Pelecypoda															

Table N5-4

Tolerance Values and Densities for Most Common Taxa in Detention Ponds (organism density in number/m³)

Taxa	TV	Pond A-1	Pond A-2	Pond A-3	Pond A-4	Pond A-5	Pond B-1	Pond B-2	Pond B-3	Pond B-4	Pond B-5	Pond C-1	Pond C-2	Pond D-1	Pond D-2
Sphaeriidae	8					624									
Density-weighted TV		5.2	8.9	5.6	6.1	6.9	6.9	8.4	8.0	7.0	5.7	6.1	6.9	5.6	8.3
Taxa Mean TV		6.7	7.8	7.5	7.5	7.3	7.8	8.0	8.0	7.7	7.0	7.0	8.0	7.5	7.9
Weighted TV Rank		1	14	2	6	7	8	13	11	10	4	5	9	3	12

Table N5-5
Sediment Bioassay Test Results

Test Media	Sample Date	Hyalella azteca						Chironomus tentans					
		Control % Survival	Test % Survival	Survival T Statistic	Survival T _{0.05} Value	Control Mean Wt. ¹	Test Mean Wt.	Mean Wt. T Statistic	Control % Survival	Test % Survival	Survival T Statistic	Survival T _{0.05} Value	
Pond A-1	10/29/92	74 ⁷	95	NA	NA	0.06	0.11	NA	NA ⁴	NA	NA	NA	
Pond A-2	11/12/92	74 ⁷	89	NA	NA	0.06	0.15	NA	NA	NA	NA	NA	
Pond A-3	10/21/92	89	76	0.971	2.46	0.13	0.10	NA	82	103 ⁵	-2.618 ⁶	2.46	
Pond A-4	10/19/92	89	99	-0.777	2.46	0.13	0.17	NA	82	73	1.007	2.46	
Pond A-5	11/19/92	38 ⁷	89	NA	NA	0.06	0.33	NA	NA	NA	NA	NA	
Pond B-1	11/16/92	85	91	-1.094	2.18	0.05	0.16	NA	NA	NA	NA	NA	
Pond B-2	11/18/92	85	64	3.72 ⁸	2.18	0.05	0.14	NA	NA	NA	NA	NA	
Pond B-3	10/27/92	89	84	0.388	2.46	0.13	0.11	NA	82	88	-0.805	2.46	
Pond B-4	10/22/92	89	91	-0.194	2.46	0.13	0.19	NA	82	62	2.416	2.46	
Pond B-5	10/20/92	89	60	2.233	2.46	0.13	0.12	NA	82	72	1.208	2.46	
Pond C-1 ²	11/9/92	74 ⁷	80	NA	NA	0.06	0.14	NA	NA	NA	NA	NA	
Pond C-1 ³	11/9/92	74 ⁷	94	NA	NA	0.06	0.10	NA	NA	NA	NA	NA	
Pond C-2	11/10/92	74 ⁷	96	NA	NA	0.06	0.16	NA	NA	NA	NA	NA	

¹ Mean Weight in grams

² Sediment material from

³ Sediment material from

⁴ Tests not conducted

⁵ Sample showed evidence of reproduction

⁶ Statistically higher than control; attributed to resident *Chironomus* in test sediments

⁷ Control treatment below acceptable test limit of 80 percent survival

⁸ Statistically lower than control treatment

NA - data not available

Table N5-6
Community Structure and Hazard Index Correlation

	Pond A-1	Pond A-2	Pond A-3	Pond A-4	Pond A-5	Pond B-1	Pond B-2	Pond B-3	Pond B-4	Pond B-5	Pond C-1	Pond C-2
Richness	48	24	27	7	19	36	35	12	20	17	6	18
Density	252	103	305	85	49	175	111	550	324	269	0.6	1.2
Diversity	1.1	1.4	0.53	0.81	2.1	2.3	2.2	0.32	1	1.2	1.1	2
Tolerance Value	5.19	8.85	5.59	6.14	6.88	6.92	8.38	8	7.02	5.66	6.06	6.94
Hazard Index	155	17	59	13	16	1996	74	134	251	8.1	2.6	3

	Pond A-1	Pond A-2	Pond A-3	Pond A-4	Pond A-5	Pond B-1	Pond B-2	Pond B-3	Pond B-4	Pond B-5	Pond C-1	Pond C-2
Richness	1	5	4	11	7	2	3	10	6	9	12	8
Density	8	5	10	4	3	7	6	12	11	9	1	2
Diversity	7.5	5	11	10	3	1	2	12	9	6	7.5	4
Tolerance Value	1	12	2	5	6	7	11	10	9	3	4	8
Hazard Index	10	6	7	4	5	12	8	9	11	3	1	2

Correlation Coefficients (r^2) Values Measurement Data					
	Richness	Density	Diversity	Tolerance Value	Hazard Index
Richness	1				
Density	0.011006	1			
Diversity	0.129632	0.399592	1		
Tolerance Value	0.005185	4.31E-05	0.054014	1	
Hazard Index	0.151428	0.00484	0.166164	0.000785	1

Correlation Coefficients (r^2) Values					
Rank Order Data					
	Richness	Density	Diversity	Tolerance Value	Hazard Index
Richness	1				
Density	0.086263	1			
Diversity	0.167943	0.230266	1		
Tolerance Value	4.89E-05	0	0.076567	1	
Hazard Index	0.498851	0.46012	0.00011	0.041127	1

Table N5-7
Potential Aroclor-1254 Concentration in Fish Tissue as Estimated from Sediment Data

Pond	Sediments				Estimated from Sediment			
	Aroclor-1254 Concentration (µg/kg)	Lab Qualifier	Fraction Organic Carbon	Aroclor-1254 Concentration in Carbon (µg/kg C)	Fathead Minnows		Largemouth Bass	
					Aroclor-1254 in Lipids (µg/kg)	Aroclor-1254 in Whole Body (µg/kg) ^{1,2}	Aroclor-1254 in Lipids (µg/kg)	Aroclor-1254 in Whole Body (µg/kg) ^{1,2}
A-1	44	J	0.014	3,140	10,400	104	50,300	503
	73	J	0.014	5,210	17,200	172	83,400	834
	86	J	0.014	6,140	20,300	203	98,300	983
	86	J	0.014	6,140	20,300	203	98,300	983
	88	J	0.014	6,290	20,700	207	101,000	1,010
mean =	75			5,390	17,800	178	86,200	862
A-2	89	J	0.026	3,420	11,300	113	54,800	548
	130	J	0.026	5,000	16,500	165	80,000	800
	160	J	0.026	6,150	20,300	203	98,500	985
	480	U	0.026	NC	NC	NC	NC	NC
mean =	215			4,860	16,000	160	77,700	777
A-3	45	J	0.012	3,750	12,400	124	60,000	600
	240	U	0.012	NC	NC	NC	NC	NC
	330	U	0.012	NC	NC	NC	NC	NC
	450	U	0.012	NC	NC	NC	NC	NC
	450	U	0.012	NC	NC	NC	NC	NC
mean =	303			3,750	12,400	124	60,000	600
B-1	320	J	0.023	13,900	45,900	459	223,000	2,230
	410	J	0.023	17,800	58,800	588	285,000	2,850
	910		0.023	39,600	131,000	1,310	633,000	6,330
	1100		0.023	47,800	158,000	1,580	765,000	7,650
	1600		0.023	69,600	230,000	2,300	1,110,000	11,100
mean =	868			37,700	126,000	1,250	604,000	6,040
B-2	930		0.038	24,500	80,800	808	392,000	3,920
	1400		0.038	36,800	122,000	1,220	589,000	5,900
	2000		0.038	52,600	174,000	1,740	842,000	8,420
	2100		0.038	55,300	182,000	1,820	884,000	8,840
	3800		0.038	100,000	330,000	3,300	1,600,000	16,000
mean =	2,046			53,800	178,000	1,780	861,000	8,620
B-3	230	J	0.018	12,800	42,200	422	204,000	2,040
	260	J	0.018	14,400	47,700	477	231,000	2,310
	300		0.018	16,700	55,000	550	267,000	2,670
	770		0.018	42,800	141,000	1,410	684,000	6,840
	1300		0.018	72,200	238,000	2,380	1,160,000	11,600
mean =	572			31,800	105,000	1,050	508,000	5,080
B-4	120	J	0.013	9,230	30,500	305	148,000	1,480
	190	J	0.013	14,600	48,200	482	234,000	2,340
	200	J	0.013	15,400	50,800	508	246,000	2,460
	210	J	0.013	16,200	53,300	533	258,000	2,590
	220	J	0.013	16,900	55,800	558	271,000	2,710
mean =	188			14,500	47,700	477	231,000	2,310

U - undetected

J - estimated and below detection limit

NC - not calculated

¹ assume 1% lipid in whole body

² BSF = 3.3 for fathead minnow; BSF = 16 for bass

Table N5-8
Aroclor-1254 in Aquatic Biota Collected from A- and B-Series Detention Ponds

Pond	Biota Type	Number of Samples	Detection Frequency	Mean¹ (µg/kg)	Standard Deviation¹ (µg/kg)
A-1	None	NA	NA	NA	NA
A-2	Benthos	1	1/1	20	NA
A-2	Crayfish	4	0/4	NA	NA
A-2	Largemouth bass	3	3/3	48	9.1
A-3	Crayfish	4	0/4	NA	NA
A-4	Crayfish	3	0/3	NA	NA
A-4	Fathead Minnow	3	3/3	17	5.8
A-5	Crayfish	3	0/3	NA	NA
A-5	Fathead Minnow	5	3/5	73	41
B-1	Salamander larvae	2	2/2	33	9.9
B-2	Salamander larvae	2	2/2	120	21
B-3	None	NA	NA	NA	NA
B-4	Fathead minnow	6	3/6	480	17
B-5	Crayfish	3	0/3	NA	NA
B-5	Fathead minnow	3	3/3	160	17

¹ Mean and standard deviation values were calculated using the values reported for the "real" Aroclor-1254 detections.
NA - not applicable

Table N5-9
Aroclor-1254 Concentration Ratios in Sediment and Biological Tissues¹

Pond ² (species)	Concentration in Sediments		Concentration in Biological Tissues		Aroclor-1254 Concentration Ratios	
	Bulk Sediment (µg/kg)	Organic Carbon (µg/kg C)	Whole Body (µg/kg)	Lipids ³ (µg/kg lipid)	Whole Body/Bulk Sediment	Lipid/Organic Carbon (BSF)
A-2 (largemouth bass)	215	8,270	48	4,800	0.2	0.6
A-2 (benthos)	215	8,270	20	2,000	0.1	0.2
B-1 (tiger salamander)	868	37,700	40	4,000	0.0	0.1
B-2 (tiger salamander)	2,050	89,000	134	13,000	0.1	0.2
B-4 (fathead minnow)	188	14,500	480	48,000	2.6	3.3

¹mean for pond

²data presented only for ponds from in which Aroclor-1254 was detected in both sediment and biota

³assume 1 % lipids

Table N5-10

Aroclor-1254 Concentrations in Sediment and Fish Tissue Resulting in Ingestion Rates Equivalent to the TRV for Mallard and Great Blue Heron
Estimated for Different Levels of Site Use

Species	Trophic Levels Present ¹	PCB Concentration in Sediment (mg/kg carbon)	BSF ²	PCB Concentration in Lipids ³ (mg/kg)	PCB Concentration in Whole Body ³ (mg/kg)	Food Ingestion ⁴ (kg/day)	a	Site Use Factor	Body Weight (kg)	TRV (mg/kg bw/day)
Mallard	3 - forage fish	1,230	3.3	4,000	40	0.084	0.9	0.1	1.8	0.17
		613	3.3	2,000	20	0.084	0.9	0.2	1.8	0.17
		409	3.3	1,300	13	0.084	0.9	0.3	1.8	0.17
		307	3.3	1,000	10	0.084	0.9	0.4	1.8	0.17
		245	3.3	810	8.1	0.084	0.9	0.5	1.8	0.17
		204	3.3	680	6.7	0.084	0.9	0.6	1.8	0.17
		175	3.3	580	5.8	0.084	0.9	0.7	1.8	0.17
		153	3.3	510	5.1	0.084	0.9	0.8	1.8	0.17
		136	3.3	450	4.5	0.084	0.9	0.9	1.8	0.17
		123	3.3	400	4.0	0.084	0.9	1	1.8	0.17
Heron	3 - forage fish	1,070	3.3	3,500	35	0.10	0.9	0.1	2.3	0.14
		537	3.3	1,800	18	0.10	0.9	0.2	2.3	0.14
		358	3.3	1,200	12	0.10	0.9	0.3	2.3	0.14
		268	3.3	890	8.9	0.10	0.9	0.4	2.3	0.14
		215	3.3	710	7.1	0.10	0.9	0.5	2.3	0.14
		179	3.3	590	5.9	0.10	0.9	0.6	2.3	0.14
		153	3.3	510	5.1	0.10	0.9	0.7	2.3	0.14
		134	3.3	440	4.4	0.10	0.9	0.8	2.3	0.14
		119	3.3	390	3.9	0.10	0.9	0.9	2.3	0.14
		107	3.3	350	3.5	0.10	0.9	1	2.3	0.14
Heron	4 - forage fish and aquatic predators ⁵	221	16	3,500	35	0.10	0.9	0.1	2.3	0.14
		111	16	1,800	18	0.10	0.9	0.2	2.3	0.14
		73.8	16	1,200	12	0.10	0.9	0.3	2.3	0.14
		55.3	16	890	8.9	0.10	0.9	0.4	2.3	0.14
		44.3	16	710	7.1	0.10	0.9	0.5	2.3	0.14
		36.9	16	590	5.9	0.10	0.9	0.6	2.3	0.14
		31.6	16	510	5.1	0.10	0.9	0.7	2.3	0.14
		27.7	16	440	4.4	0.10	0.9	0.8	2.3	0.14
		24.6	16	390	3.9	0.10	0.9	0.9	2.3	0.14
		22.1	16	350	3.5	0.10	0.9	1	2.3	0.14

¹Trophic levels according to ORNL 1994

²Ratio of $[\text{PCB}]_{\text{lipid}} : [\text{PCB}]_{\text{organic carbon}}$ (Macdonald *et al.* 1993)

³Assume 1 percent lipid in fish tissue

⁴Dry matter; calculated according to EPA 1993 equation 3-5

⁵Estimated according to Fordham and Regan (1992)

Table N5-11

A. Summary of Mercury Distribution in OU5

	PCOC	Detection Frequency	Maximum Detected Concentration	Units
Surface Soil	yes	39/91 (43%)	0.66	mg/kg
Subsurface Soil	no	--	--	--
Groundwater	yes	5/17 (29%)	3.0	µg/L
Surface Water	no	--	--	--
dissolved	--	2/35 (6%)	1.0	µg/L
total	--	2/37 (5%)	0.10	µg/L
Stream Sediments	yes	1/8 (12%)	3.1	mg/kg
Pond Sediments	yes	6/6 (100%)	1.6	mg/kg
Fish	N/A	2/13 (15%)	0.47	mg/kg

N/A - not applicable

B. Summary of Mercury Distribution in OU6

	PCOC	Detection Frequency	Maximum Detected Concentration	Units
Surface Soil	yes	70/119 (41%)	0.30	mg/kg
Subsurface Soil	no	72/231 (31%)	0.90	--
Groundwater	yes	11/107(10%)	1.5	µg/L
Surface Water	no	--	--	--
dissolved	no	11/51 (22%)	0.60	µg/L
total	no	17/51 (33%)	1.5	µg/L
Stream Sediments	yes	1/8 (12%)	3.1	mg/kg
Pond Sediments	no	24/56 (43%)	1.5	mg/kg
Fish	N/A	8/12 (67%)	0.060	mg/kg

N/A - not applicable

Table N5-12

A. Chromium in Terrestrial Arthropod (TA) Samples from the OU2 Source Areas

Source Area (SA)	Location	Chemical	Result	Units	Qualifier	Detection Limit
903 Pad	MG09A2	Chromium	2.1	mg/kg		10
903 Pad SA Exp Pt Conc = 131 mg/kg (based on ratio of TA to soil in East Trenches SA) [†]						
East Trenches	MX07A2	Chromium	1.6	mg/kg	U	10
East Trenches	MX03A2	Chromium	2.3	mg/kg		10
East Trenches	MG07A2	Chromium	45	mg/kg	U ²	10
East Trenches	MG07A2	Chromium	75	mg/kg		10
East Trenches SA Exp Pt Conc = 63.5 mg/kg (UCL ₉₅)						
Mound Area	no TA data available					
Mound Area SA Exp Pt Conc = 62.8 mg/kg (based on ratio of TA to soil in East Trenches SA) [†]						

U - undetected; analyzed for but not detected

¹Because adequate TA samples were not available, chromium concentrations were estimated from the ratio of chromium in TAs to chromium in surficial soil for the East Trenches SA.

²Contract Required Detection Limit check sample recovery criteria were not met.

B. Chromium in Surficial Soil Samples from the OU2 Source Areas

Source Area (SA)	Location	Chemical	Result	Units	Qualifier	Detection Limit
903 Pad	PT015	Chromium	5.40	mg/kg		2
903 Pad	PT028	Chromium	6.00	mg/kg		2
903 Pad	PT016	Chromium	6.70	mg/kg		2
903 Pad	PT034	Chromium	7.20	mg/kg		2
903 Pad	PT031	Chromium	8.60	mg/kg		2
903 Pad	PT037	Chromium	10.8	mg/kg		2
903 Pad	SS200693	Chromium	10.8	mg/kg		10
903 Pad	SS200493	Chromium	11.3	mg/kg		10
903 Pad	RA026	Chromium	13.5	mg/kg		2
903 Pad	SS200193	Chromium	26.0	mg/kg		10
903 Pad	SS200893	Chromium	29.5	mg/kg		10
881 Hillside/903 Pad	RA030	Chromium	10.0	mg/kg		2
881 Hillside/903 Pad	PT021	Chromium	10.1	mg/kg		2
881 Hillside/903 Pad	RA025	Chromium	11.1	mg/kg		2
881 Hillside/903 Pad	RA019	Chromium	12.8	mg/kg		2
881 Hillside/903 Pad	RA024	Chromium	13.5	mg/kg		2
881 Hillside/903 Pad	RA023	Chromium	14.9	mg/kg		2
881 Hillside/903 Pad	RA022	Chromium	15.5	mg/kg		2
881 Hillside/903 Pad	RA027	Chromium	17.4	mg/kg		2
881 Hillside/903 Pad	RA031	Chromium	77.0	mg/kg		2
881 Hillside/903 Pad	RA031	Chromium	80.5	mg/kg		2
903 Pad SA Exp Pt Conc = 26.8 mg/kg (UCL ₉₅) ¹						
East Trenches	PT076	Chromium	6.70	mg/kg		2
East Trenches	PT053	Chromium	9.20	mg/kg		2
East Trenches	PT074	Chromium	9.60	mg/kg		2
East Trenches	SS201193	Chromium	9.90	mg/kg		10
East Trenches	PT067	Chromium	10.2	mg/kg		2
East Trenches	PT079	Chromium	10.6	mg/kg		2
East Trenches	PT072	Chromium	11.9	mg/kg		2
East Trenches	SS200793	Chromium	13.0	mg/kg		2
East Trenches	SS201393	Chromium	14.2	mg/kg		10
East Trenches	SS201293	Chromium	15.3	mg/kg		10
East Trenches	SS200993	Chromium	15.5	mg/kg		2
East Trenches SA Exp Pt Conc = 13.0 mg/kg (UCL ₉₅)						
Mound Area	SS200393	Chromium	9.20	mg/kg		2
Mound Area	SS200293	Chromium	10.2	mg/kg		2
Mound Area SA Exp Pt Conc = 10.2 (maximum detected concentration)						

¹The 903 Pad SA exposure point concentration includes samples within OU1 (881 Hillside)

Table N5-13
Summary of American Kestrel ECOCs in OU4/OU6 Surface and Subsurface Soils¹

OU6					Background	
Concentration (mg/kg)					Concentration (mg/kg)	
	Mean	Standard Deviation	Mean Different from Background?	Number of Hits > UTL _{99/99}	Mean	Standard Deviation
Surface Soils						
Chromium	12	4.6	N	1/119	15	2.5
Lead	29	15	N	2/119	38	6.00
Mercury	0.10 ²	—	Y	0/119	0.10	—
Vanadium	33	11	N	1/119	32	6.00
Subsurface Soils						
Chromium	11	19	N	3/231	20	24
Lead	12	7.8	N	2/231	11	7.00
Mercury	0.10	0.10	N	0/231	0.30	0.60
Vanadium	23	12	N	1/231	32	29

¹Source: Technical Memorandum No. 4, Human Health Risk Assessment, Walnut Creek Priority Drainage (Operable Unit No. 6)

²Detection limit

— - Standard deviation not calculated because of low detection frequency

Table N5-14
Summary of ECOC Concentrations in Small Mammals in the OU4/OU6 Area
of the Upper Walnut Creek Watershed

Source Area	Chromium		Lead		Mercury		Vanadium	
	Result	Q	Result	Q	Result	Q	Result	Q
OU4 Downgradient	2.4	U	1.2	U	0.18	U	1.5	U
OU4 Downgradient	2.4	U	1.2	U	0.38		1.5	U
OU4 Downgradient	2.5	U	1.3	U	0.17	U	1.6	U
A-Ponds	2.4	U	1.1	U	0.17	U	1.5	U
A-Ponds	2.2	U	0.88	U	0.15	U	1.4	U
A-Ponds	2.3	U	1.1	U	0.18	U	1.5	U
A-Ponds	45		67		3.3	U	28	U
A-Ponds	31		27		1.9	U	20	U
A-Ponds	38		54		2.9	U	24	U
A-Ponds	8.5		6.4		0.64	U	7.1	
A-Ponds	82		200		2.5	U	22	U
A-Ponds	15		11		1.1	U	9.6	U
Soil Dump Areas	2.4	U	1.2	U	0.28		1.5	U
Soil Dump Areas	2.3	U	1.0	U	0.16	U	1.5	U
Soil Dump Areas	2.5	U	1.1	U	0.18	U	1.6	U
Soil Dump Areas	2.4	I	3.5	I	0.24		1.5	U
Soil Dump Areas	2.6	U	1.0	U	0.39		1.7	U
Soil Dump Areas	2.5	U	1.1	U	0.19	U	1.6	U
B-Ponds	2.2	U	1.0	U	0.22		1.4	U
B-Ponds	2.3	U	1.2	U	0.17	U	1.5	U
B-Ponds	2.4	U	0.91	U	0.48		1.5	U
B-Ponds	37		41		2.8	U	23	U
B-Ponds	21	I	30	I	1.6	U	14	U
B-Ponds	55	I	180	I	3.6	U	35	
B-Ponds	11	U	17	U	0.85	U	7.0	U
B-Ponds	65		92		3.6	U	34	U
B-Ponds	28		25		2.0	U	18	U
Minimum	2.2		0.88		0.15		1.4	
Mean¹	17		28		1.1		9.8	
Maximum	82		200		3.6		35	
Standard Deviation	22		52		—		—	

¹ Means calculated by replacing non-detects (U-qualified) values with instrument detection limits

Q = Qualifier

blank = unqualified

U = analyzed for but not detected

I = interference

Table N5-15
Simulation of ECOC Uptake by American Kestrels Feeding in OU6

ECOC Concentrations in Small Mammals in Upper Walnut Creek (mg/kg)										
ECOC	Minimum	Mean	Standard Deviation	Maximum	Site Use Factor	Small Mammal Ingestion Rate (kg/kg)	ECOC Intake Rate ¹ (mg/kg bw/day)	TRV (mg/kg bw/day)	Probability of Exceeding TRV (%)	Probability of Exceeding Background Intake (%)
Site Intake										
Chromium	2.2	17	22	82	1.0	0.29	3.1	2.2	63	55
Lead	0.90	28	52	200	1.0	0.29	3.9	3.8	50	100
Background Intake										
Chromium	2.1	6.0	3.0	20	1.0	0.29	1.7	2.2	23%	NA
Lead	0.93	1.9	0.60	4.1	1.0	0.29	0.60	3.8	0%	NA

¹ Geometric mean from simulation data; simulation based on lognormal distribution of ECOC concentrations in small mammals.
NA - not applicable

Table N5-16
Subsurface Soil Toluene Concentrations Resulting in
Estimated Burrow Air Concentrations \geq Toxicity Reference Value

Sample Location	Sample Date	($\mu\text{g/kg}$)	Qualifier
OU2 East Trenches			
06591	03/03/92	390	—
21893	05/25/93	400	—
06791	02/13/92	480	D
08791	02/21/92	550	D
06591	03/03/92	970	—
21893	05/25/93	2,000	—
OU2 903 Pad			
24093	08/16/93	400	—
10491	12/12/91	430	D
08291	01/22/92	480	D
10291	12/06/91	670	J
10191	12/03/91	1,100	J
10191	12/03/91	1,400	J
22493	04/28/93	2,800	—
22493	04/28/93	3,100	—
24793	08/09/93	7,600	J

Concentration resulting in estimated burrow air concentration \geq Toxicity Reference Value = 388 $\mu\text{g/kg}$

Detection Frequency = 155/227

Proportion of Hits > TRV = .04

— - no qualifier (measured value)

D - Estimated value; identified in analysis at secondary dilution

J - Estimated value; data from mass spectrophotometer indicate presence of compound but concentration below detection limit

Table N5-17
Subsurface Soil PCOCs with Hazard Quotients > 1 for Vegetation
Detection Frequencies and Variability Among Detected Concentrations

Source Area	Subsurface Soil PCOC	Detection Frequency	Number of Samples with Concentrations \geq TRV	UCL ₉₅ Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Maximum Location	Standard Deviation
OU2 903 Pad	Zinc	114/114	45/114	58.9	200	65912	36.8
OU2 Mound Area	Zinc	11/11	7	69.8	99.1	21793	29.8
OU4 Downgradient	Nitrate/Nitrite	14/14	2	91.2	387	40593	106
	Zinc	14/14	8	68.8	115	40593	23.8
	Lead	14/14	1	66.6	278	40593	70.7
OU5 Ash Pits	Chromium	137/138	18	176	8,310	56893	706
	Nickel	132/138	13	109	4,750	56893	403
	Zinc	138/138	45	151	2,390	55993	317
	Silver	15/116 ¹	10	14.7	311	55993	37.9
	Antimony	20/131 ¹	54 ²	9.48	149	56893	15.1
	Copper	138/138	8	113	2,920	56393	299
	Lead	138/138	8	55.6	935	55993	125
	Cadmium	18/138	7	3.14	56.9	56393	7.51
OU5 Old Landfill	Copper	81/81	3	262	6,920	59493	770
	Zinc	81/81	35	102	673	59493	122
OU5 C-Ponds	Chromium	5/5	3	62	73.9	50292	26
	Zinc	5/5	2	55.3	58.2	51193	16
OU6 A-Ponds	Zinc	2/2	1	78.5	50.3	41091	7.50
OU6 Soil Dump Areas	Strontium	118/118	72	102	506	78492	78.7
	Zinc	81/81	19	51.1	706	73692	67.8
OU6 North Spray Field	Chromium	44/44	3	28.6	217	63192	34.5
	Zinc	44/44	5	50.4	287	63092	50.5
OU6 Burial Trenches	Strontium	52/53	23	96.2	264	68892	63.6
OU7 Downgradient Area	Nitrate/Nitrite	3/17 ¹	1	3230	20,000	71093	4850
	Strontium	19/19	12	101	197	71093	35.0
	Zinc	19/19	17	73.8	99.2	70993	14.0

¹Detection frequency < 50%

²TRV is lower than the detection limit

PCOC - Potential Chemical of Concern

TRV - Toxicity reference value

UCL95 - 95% upper confidence limit of the mean

Table N5-18
Radionuclide Concentrations in Soil vs. Small Mammal Tissue¹
(pCi/g)

Source Area	Chemical	Surface Soil Concentrations ²	Small Mammal Concentrations ²
OU1 881 Hillside	Americium-241	2.61	0.0019
OU 2 903 Pad	Americium-241	41.2	0.061
OU5 Ash Pits	Americium-241	0.0235	0.0014
OU6 B-Ponds	Americium-241	0.270	0.0038
OU5 C-Ponds	Americium-241	2.09	0.0043
OU7 Downgradient Areas	Americium-241	0.0270	0.0030
OU2 East Trenches	Americium-241	10.2	0.0090
OU5 Old Landfill	Americium-241	0.0201	0.0014
OU4 Downgradient	Americium-241	0.133	0.0020
OU6 Soil Dump Areas	Americium-241	0.903	0.00079
Background	Americium-241	0.0235	0.00054
OU1 881 Hillside	Plutonium-239/240	10.8	0.012
OU 2 903 Pad	Plutonium-239/240	697	0.40
OU5 Ash Pits	Plutonium-239/240	0.0567	0.0050
OU6 B-Ponds	Plutonium-239/240	1.03	0.0084
OU5 C-Ponds	Plutonium-239/240	11.8	0.0074
OU7 Downgradient Areas	Plutonium-239/240	0.106	0.0070
OU2 East Trenches	Plutonium-239/240	45.7	0.032
OU5 Old Landfill	Plutonium-239/240	0.0597	0.0063
OU4 Downgradient	Plutonium-239/240	0.217	0.0010
OU6 Soil Dump Areas	Plutonium-239/240	1.77	0.0023
Background	Plutonium-239/240	0.0615	0.0014
OU5 Ash Pits	Uranium-233/234	8.03	0.041
OU6 B-Ponds	Uranium-233/234	1.00	0.046
OU7 Downgradient Areas	Uranium-233/234	0.893	0.024
OU5 Old Landfill	Uranium-233/234	126	0.028
OU4 Downgradient	Uranium-233/234	1.09	0.089
OU6 Soil Dump Areas	Uranium-233/234	2.17	0.071
Background	Uranium-233/234	1.20	0.033
OU1 881 Hillside	Uranium-238	1.37	0.26
OU 2 903 Pad	Uranium-238	2.54	0.11
OU5 Ash Pits	Uranium-238	30.7	0.063
OU6 B-Ponds	Uranium-238	1.10	0.031
OU5 C-Ponds	Uranium-238	1.30	0.15
OU7 Downgradient Areas	Uranium-238	0.939	0.015
OU2 East Trenches	Uranium-238	2.15	0.13
OU5 Old Landfill	Uranium-238	1670	0.022
OU4 Downgradient	Uranium-238	1.16	0.020
OU6 Soil Dump Areas	Uranium-238	1.06	0.030
Background	Uranium-238	1.25	0.086

¹Omitted source areas do not have data for surface soil, small mammals, or both

²The lesser of the maximum detected concentration or the UCL₉₅

Table N5-19
Small Mammal Whole Body Dose Calculation and Comparison with Critical Dose Rate

Receptor	Radionuclide	Sitewide Maximum Tissue Concentration (pCi/g)	dis/min-g	Effective Absorbed Dose (MeV/dls)	ergs/MeV	min/day	ergs/g-rad	Whole Body Dose (TRV=0.1rad/day)	Body Burden Required for Critical Dose Rate (=0.1 rad/day)
Small Mammals	Plutonium-239/240	1.1	2.22	53	1.60E-06	1,440	100	2.98E-03	36.8
	Americium-241	0.16	2.22	57	1.60E-06	1,440	100	4.66E-04	34.3
	Uranium-233/234	0.11	2.22	49	1.60E-06	1,440	100	2.76E-04	39.9
	Uranium-238	0.26	2.22	43	1.60E-06	1,440	100	5.72E-04	45.5
Total								4.30E-03	

¹Calculated using Eq. 44-1

Table N5-20
Estimated Accumulation of Radionuclides in Two Aquatic Feeding Birds
After a Three-Year Exposure

Species ^{1,2}	Maximum Sediment Concentration (pCi/g)	CR	Exposure Point C _i (pCi/g)	IR (kg/day)	Assimilation ^a (unitless)	Body Mass (kg)	Biological Half-life ³ (days)	k _e (1/day)	t (days)	Body Burden (pCi/g)	Body Burden Required for Critical Dose Rate (=0.1 rad/day)
Americium-241 (Pond B-1)											
Mallard	389.4	0.0098	3.81	0.039	0.001	1.1	20,000	0.000035	1,095	1.45E-01	34.3
Great Blue Heron	389.4	0.0098	3.81	0.18	0.001	2.2	20,000	0.000035	1,095	3.35E-01	
Plutonium-239/240 (Pond B-2)											
Mallard	643.4	0.0054	3.47	0.039	0.001	1.1	65,000	0.000011	1,095	1.34E-01	36.8
Great Blue Heron	643.4	0.0054	3.47	0.18	0.001	2.2	65,000	0.000011	1,095	3.09E-01	
Uranium 233/234 (Pond B-1)											
Mallard	25.22	0.0237	0.598	0.039	0.001	1.1	100	0.00693	1,095	3.06E-03	39.9
Great Blue Heron	25.22	0.0237	0.598	0.18	0.001	2.2	100	0.00693	1,095	7.06E-03	
Uranium-238 (Pond B-1)											
Mallard	43.09	0.0221	0.952	0.039	0.001	1.1	100	0.00693	1,095	4.87E-03	45.5
Great Blue Heron	43.09	0.0221	0.952	0.18	0.001	2.2	100	0.00693	1,095	1.12E-02	

¹ Fish ingestion rate used for mallard exposure estimate due to lack of benthic macroinvertebrate data

² Fish ingestion rate used for great blue heron exposure estimate

³ Values from Killough and McKay (1976)

C_i Concentration in small mammals trapped at source areas

CR - Concentration ratio from sediments to benthic macroinvertebrates (mallard) and fish (great blue heron)

IR Ingestion rate, based on a site use factor (SUF) of 1.0

a - Assimilation efficiency

k_e - coefficient of elimination

t - exposure duration (3 years)

Table N5-21
Estimated Accumulation of Radionuclides in Three Terrestrial Predators
After a Three-Year Exposure

Receptor Species ¹	Exposure Point C _r ² (pCi/g)	IR (kg/day)	Assimilation a (unitless)	Body Mass (kg)	Biological Half-life ³ (days)	k _e (1/day)	t (days)	Body Burden (pCi/g)	Body Burden Required for Critical Dose Rate (=0.1 rad/day)
Americium-241 (903 Pad)									
Red-tailed Hawk	6.11E-02	0.098	0.001	1.1	20,000	3.47E-05	1,095	5.85E-03	
Coyote	6.11E-02	0.042	0.001	12	20,000	3.47E-05	1,095	2.30E-04	34.3
American Kestrel	6.11E-02	0.14	0.001	0.12	20,000	3.47E-05	1,095	7.66E-02	
Plutonium-239/240 (903 Pad)									
Red-tailed Hawk	3.97E-01	0.098	0.001	1.1	65,000	1.07E-05	1,095	3.85E-02	
Coyote	3.97E-01	0.042	0.001	12	65,000	1.07E-05	1,095	1.51E-03	36.8
American Kestrel	3.97E-01	0.14	0.001	0.12	65,000	1.07E-05	1,095	5.05E-01	
Uranium 233/234 (OU4 Downgradient)									
Red-tailed Hawk	8.90E-02	0.098	0.001	1.1	100	0.00693	1,095	1.14E-03	
Coyote	8.90E-02	0.042	0.001	12	100	0.00693	1,095	4.49E-05	39.9
American Kestrel	8.90E-02	0.29	0.001	0.12	100	0.00693	1,095	3.10E-02	
Uranium-238 (881 Hillside)									
Red-tailed Hawk	2.60E-01	0.098	0.001	1.1	100	0.00693	1,095	3.34E-03	
Coyote	2.60E-01	0.042	0.001	12	100	0.00693	1,095	1.31E-04	45.5
American Kestrel	2.60E-01	0.14	0.001	0.12	100	0.0069	1,095	4.37E-02	

¹ Small mammal ingestion rates used for red-tailed hawk, coyote, and American kestrel exposure estimate

² Source area with highest UCL₉₅ for each radionuclide

³ Values from Killough and McKay (1976)

Cf - Concentration in small mammals trapped at source areas

IR - Ingestion rate, based on a site use factor (SUF) of 1.0

a - Assimilation efficiency

Biological half-life -

k_e - coefficient of elimination

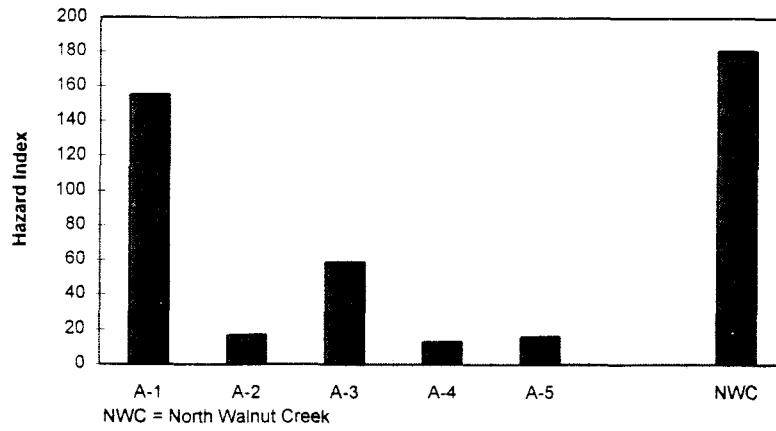
t - exposure duration (3 years)

CHAPTER N5

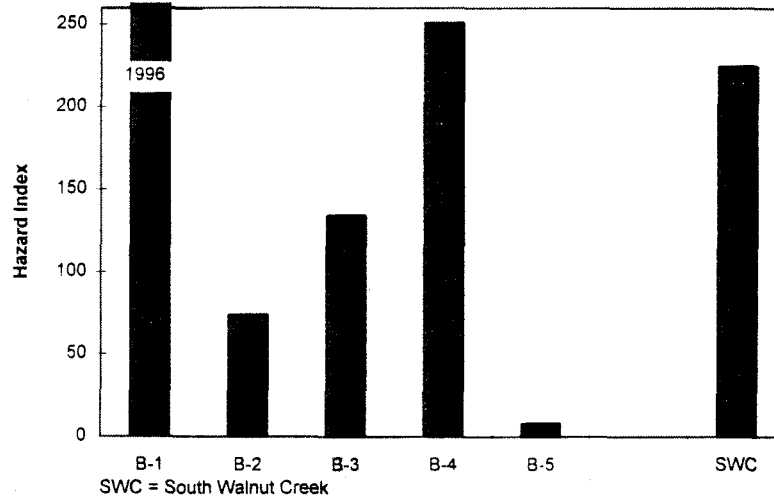
FIGURES

Figure N5-1
Pond Hazard Index Distribution

A-Series Ponds



B-Series Ponds



C-Series Ponds

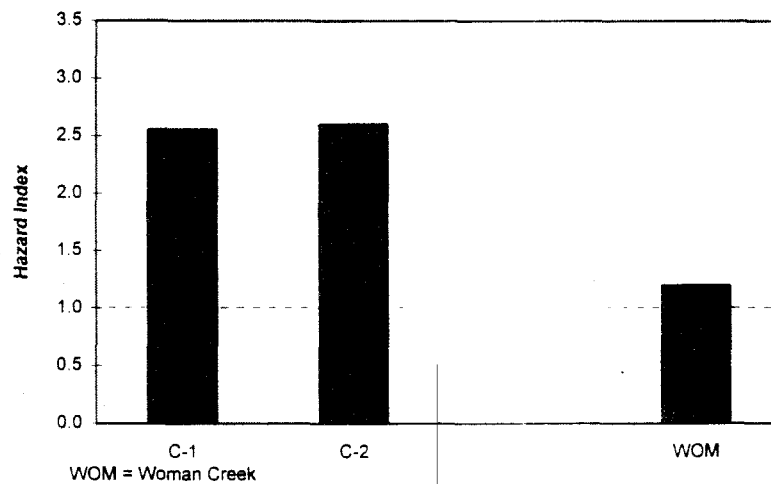
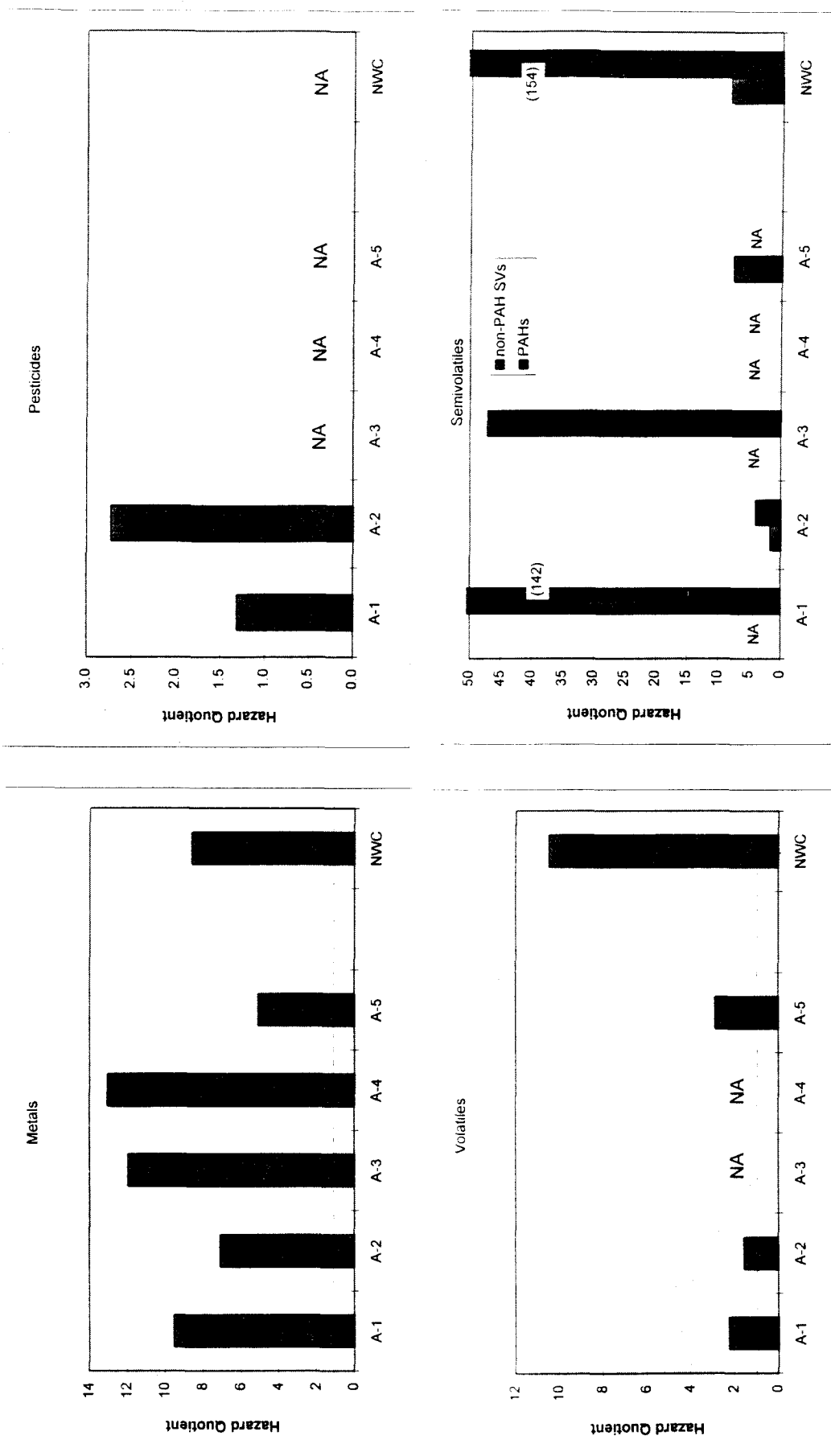
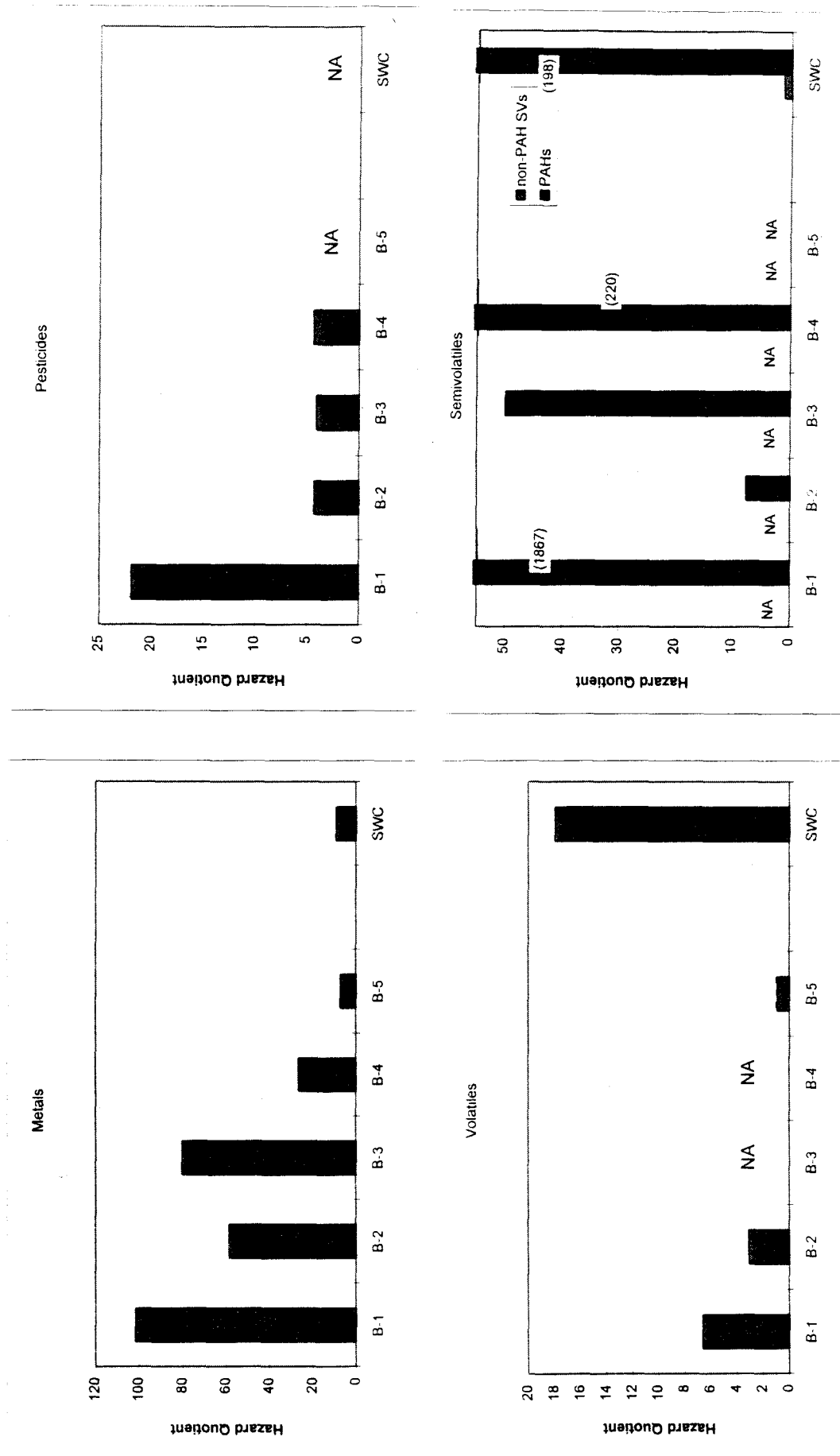


Figure N5-2
Hazard Quotients by Analyte Category for A-Series Ponds



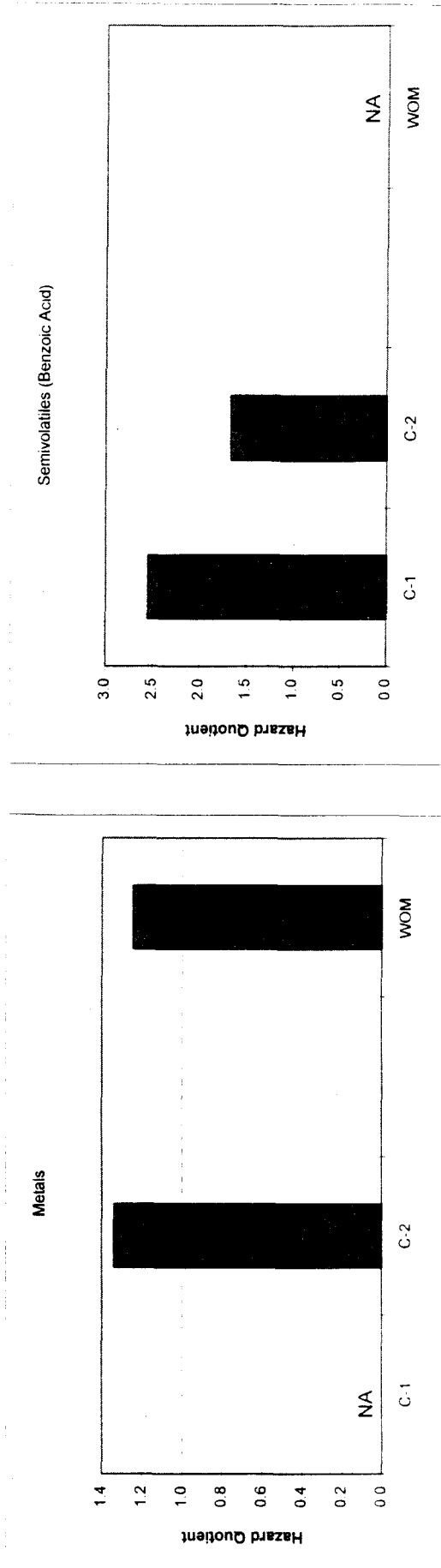
NWC = North Walnut Creek
 NA = No results in this class of compounds exceeded the TRV

Figure N5-3
Hazard Quotients by Analyte Category for B-Series Ponds



SWC = South Walnut Creek
NA = No results in this class of compounds exceeded the TRV

Figure N5-4
Hazard Quotients by Analyte Category for C-Series Ponds

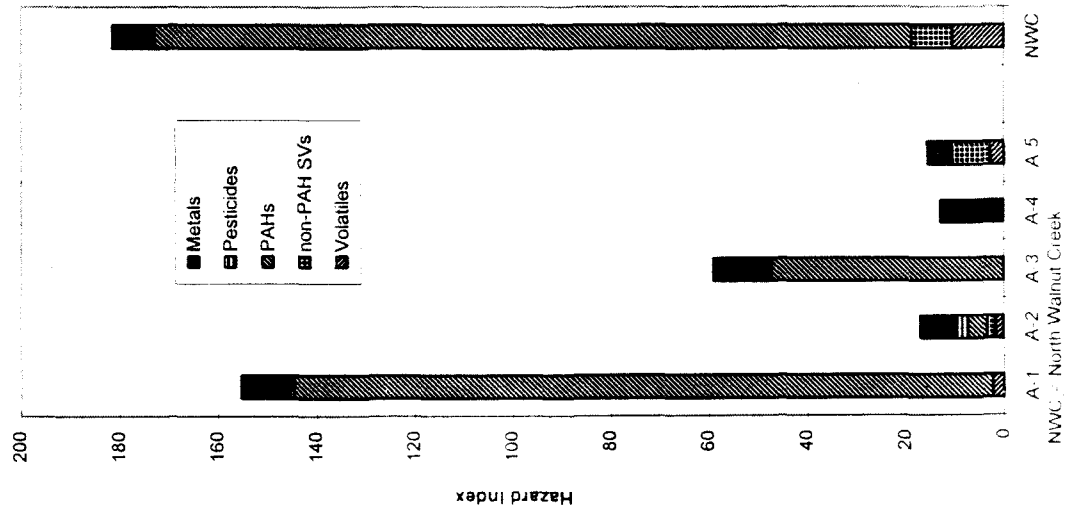


WOM = Woman Creek

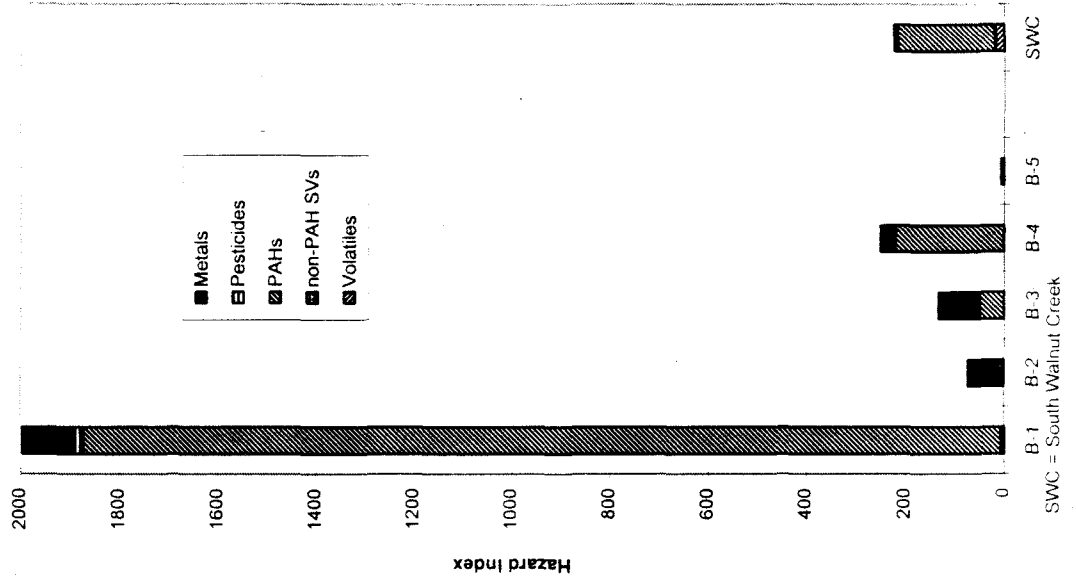
NA = No results in this class of compounds exceeded the TRV.

Figure N5-5
Hazard Index by Analyte Category

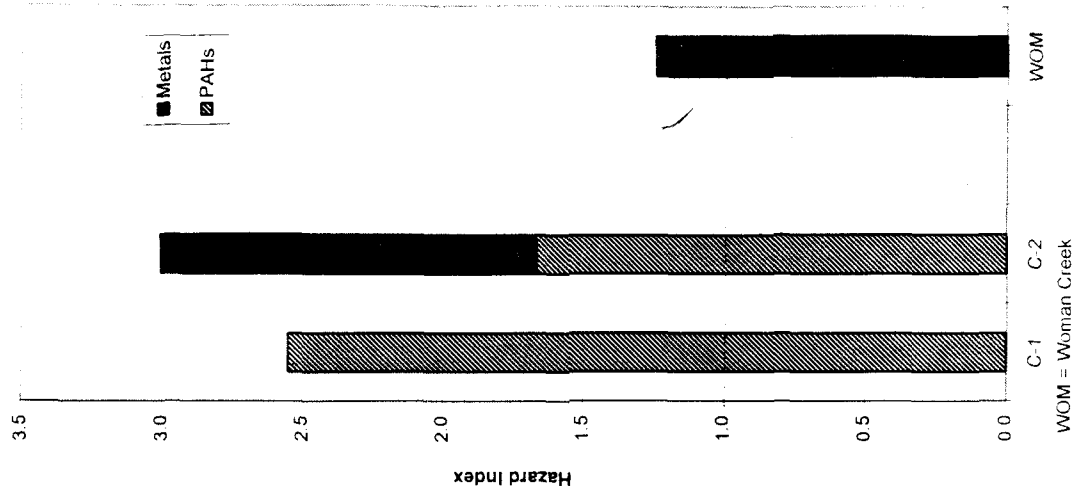
A-Series Ponds

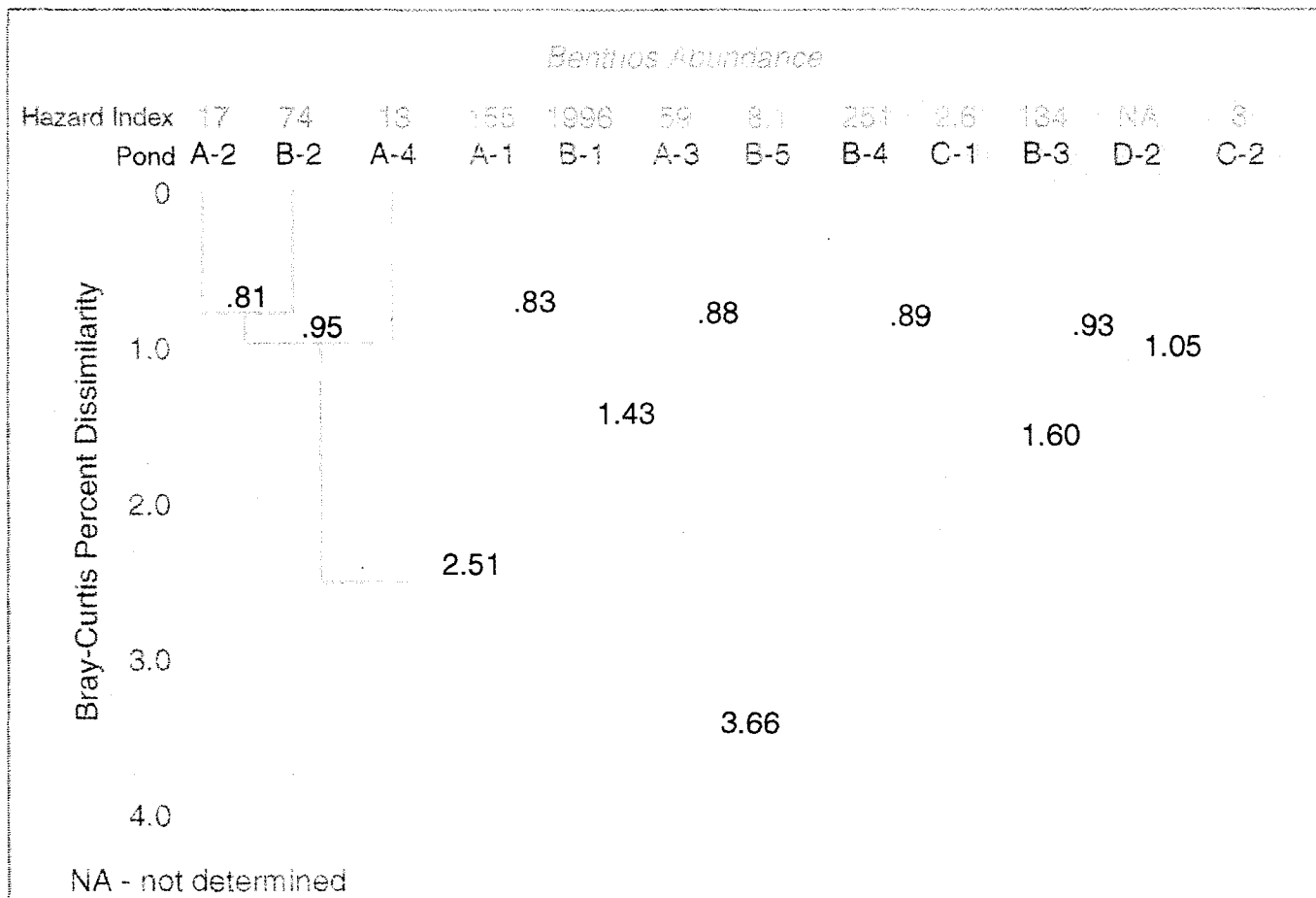


B-Series Ponds



C-Series Ponds





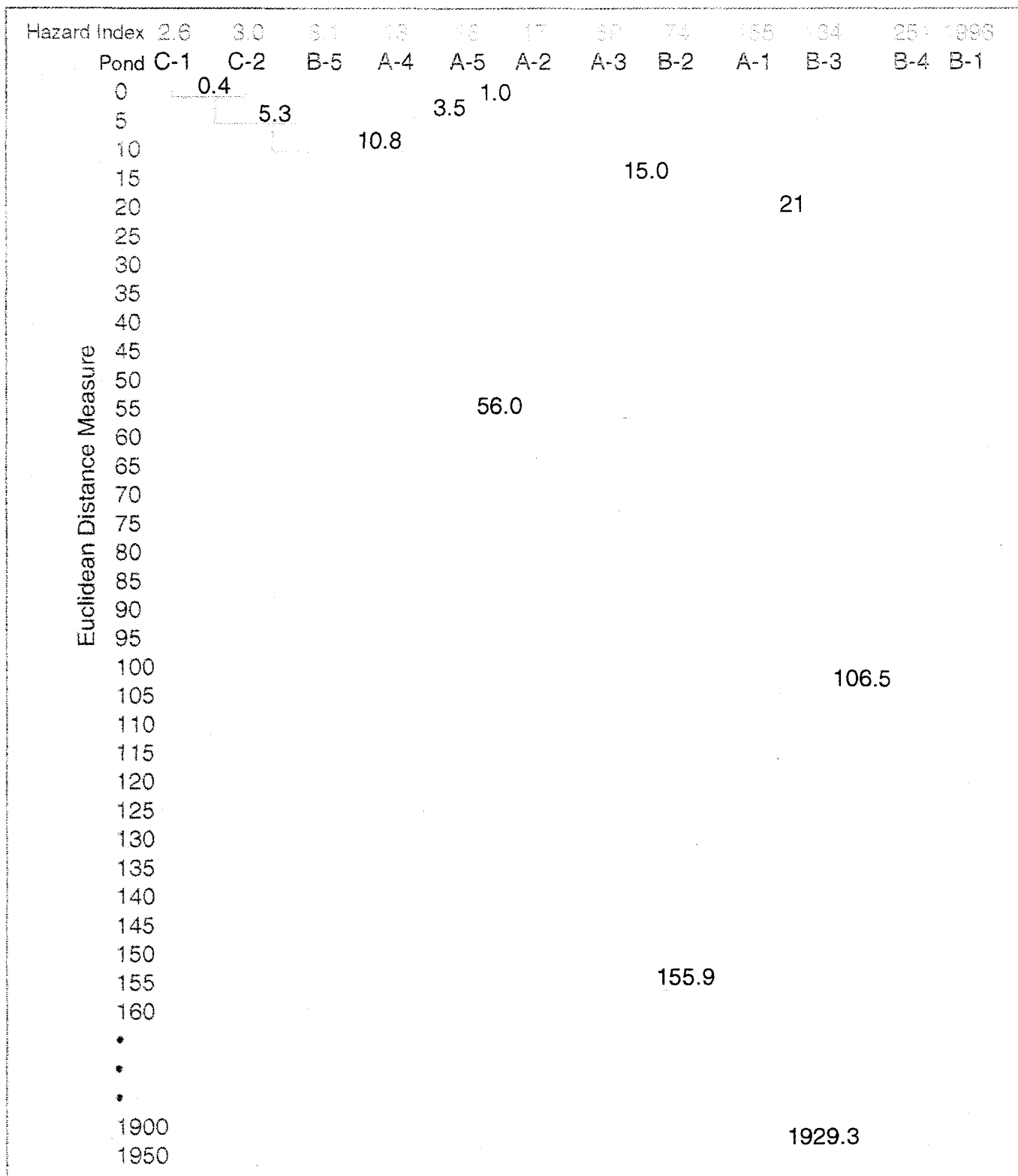
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

ERAs for Woman Creek and Walnut Creek
Watersheds at RFETS

Cluster Analysis Dendrogram
Bray-Curtis Percent Dissimilarity
Benthos Species Abundance

September 1995

Figure N5-6



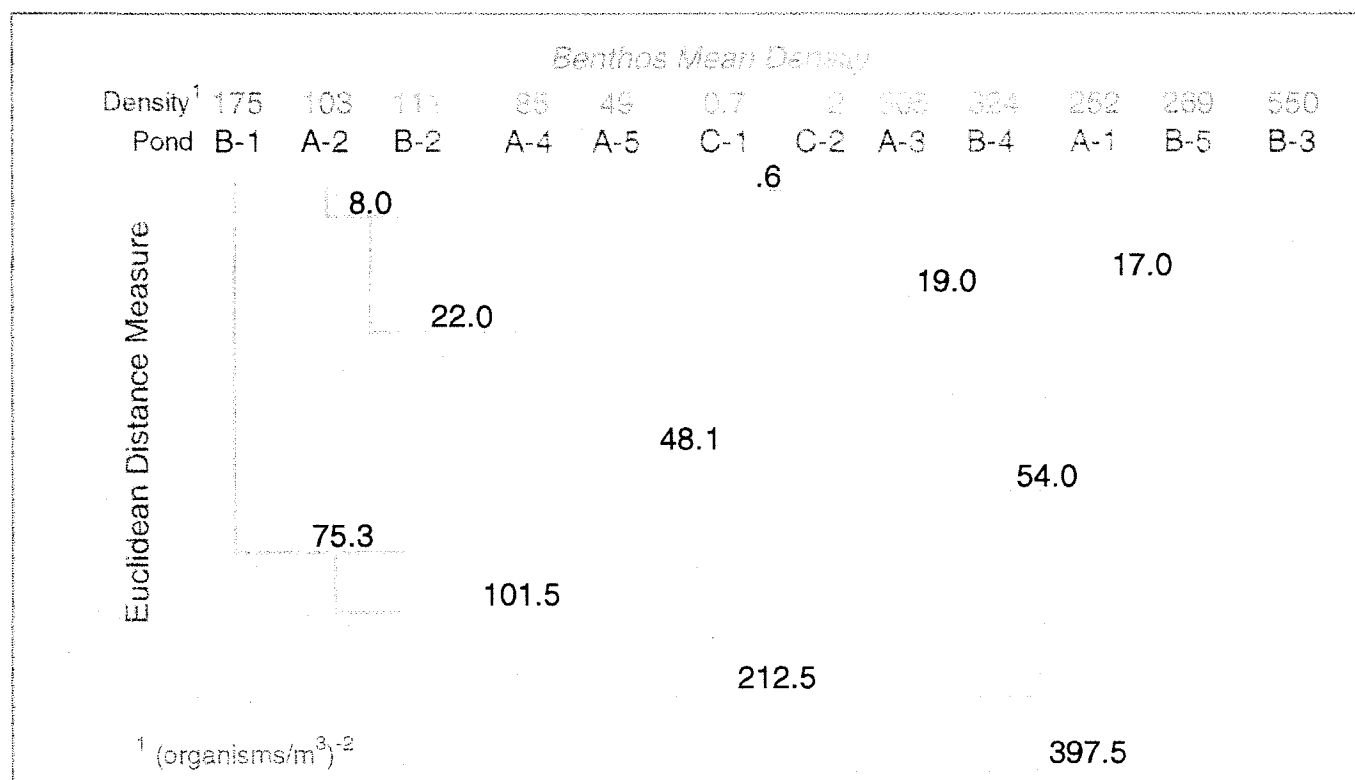
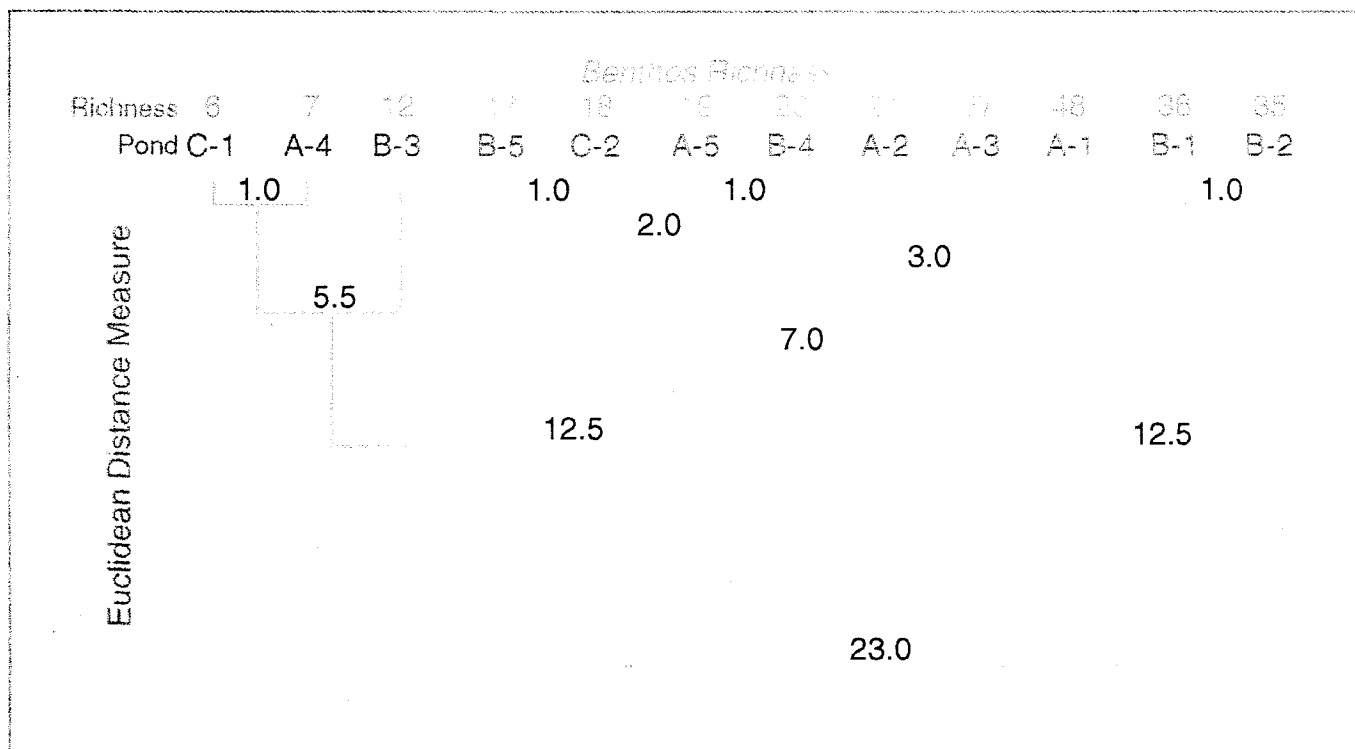
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Golden, Colorado

ERAs for Woman Creek and Walnut Creek
Watersheds at RFETS

**Cluster Analysis Dendrogram
Hazard Index**

September 1995

Figure N5-7



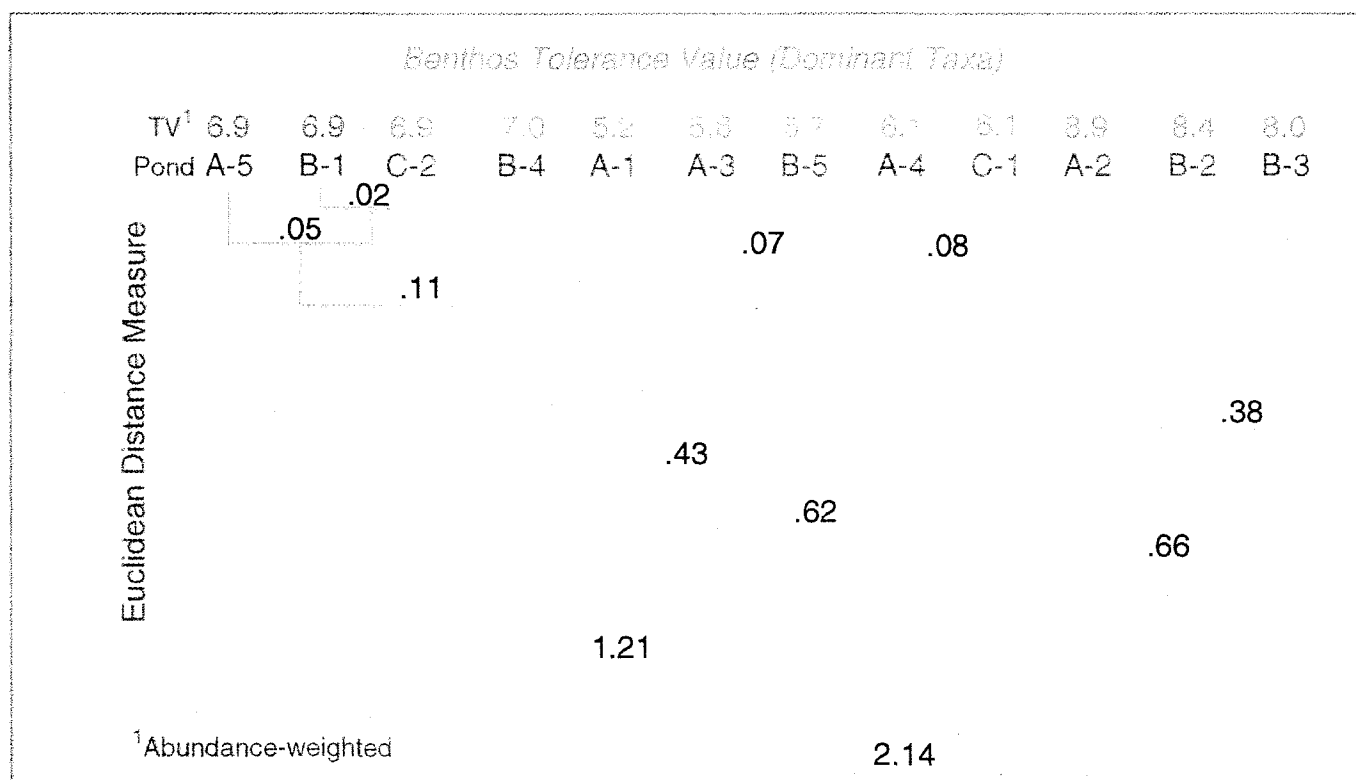
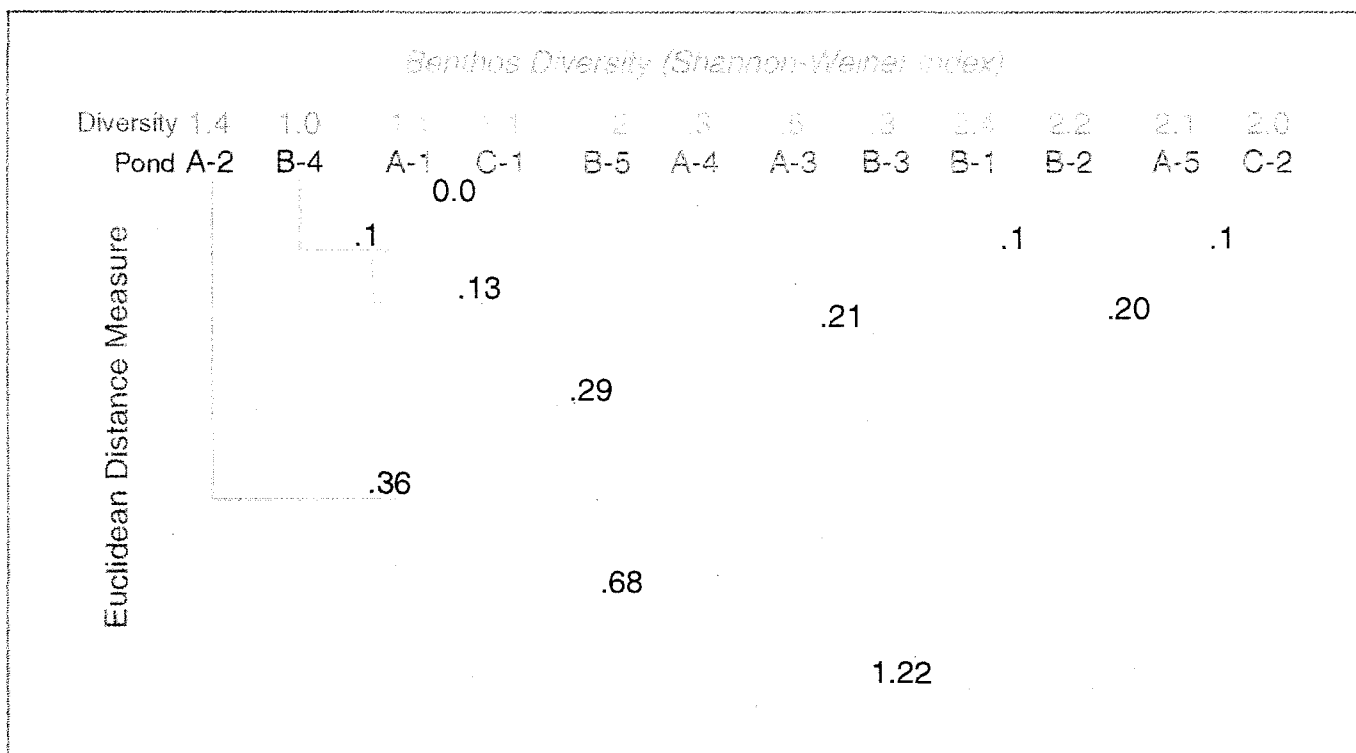
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

ERAs for Woman Creek and Walnut Creek
Watersheds at RFETS

**Cluster Analysis Dendrogram
Single Unit Pattern Expression
Benthos Richness and Density**

September 1995

Figure N5-8



U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

ERAs for Woman Creek and Walnut Creek
Watersheds at RFETS

Cluster Analysis Dendrogram
Single Unit Pattern Expression
Benthos Diversity and
Pollution Tolerance

September 1995

Figure N5-9

Figure N5-11
Mean of Total PCB Concentrations

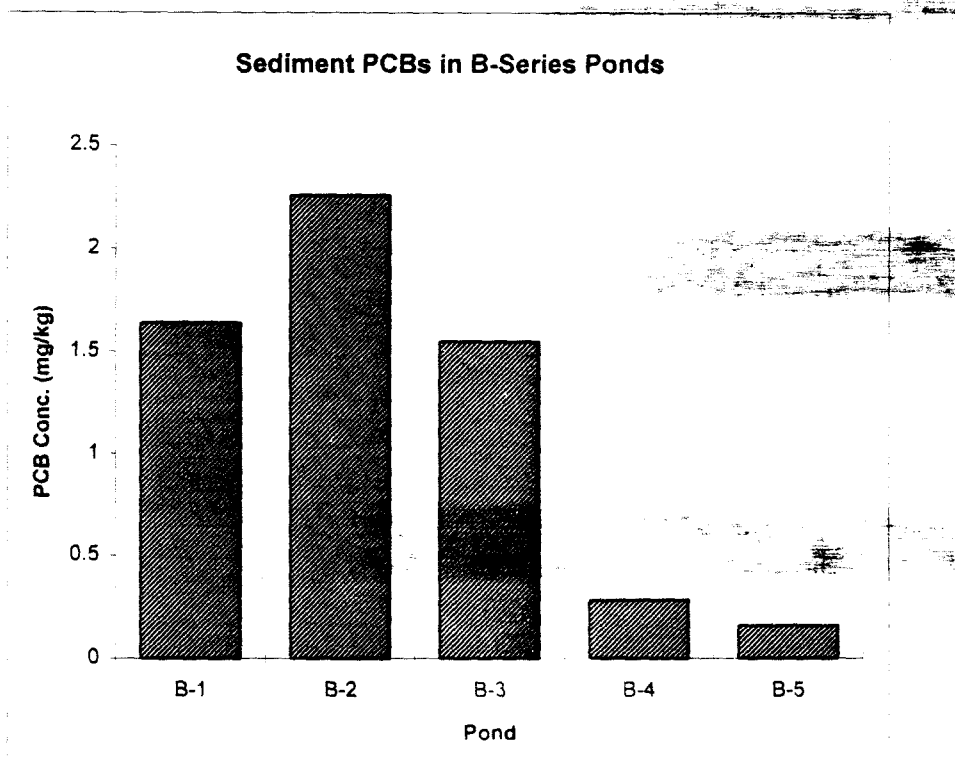
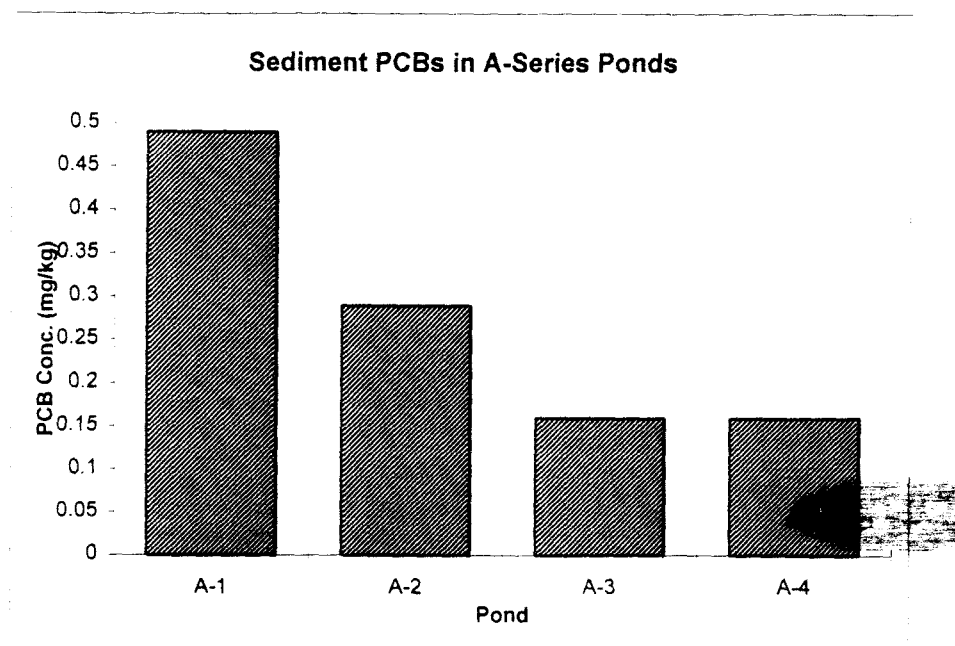


Figure N5-12
Estimation of Allowable PCB Concentrations in Sediments
Based on Different Site Use Factors

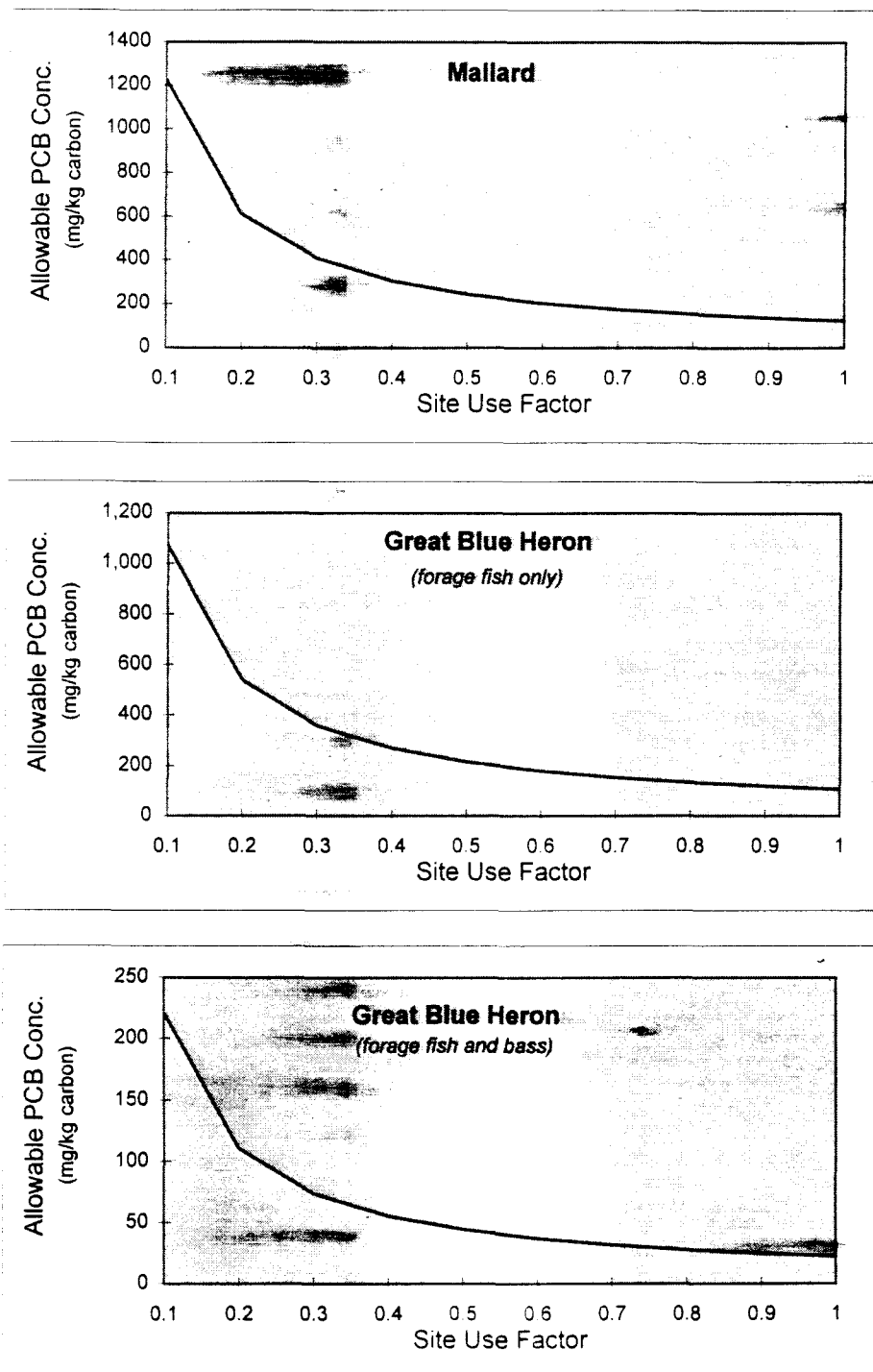


Figure N5-13
Aroclor-1254 Concentrations and Criteria for Protection of Great Blue Heron

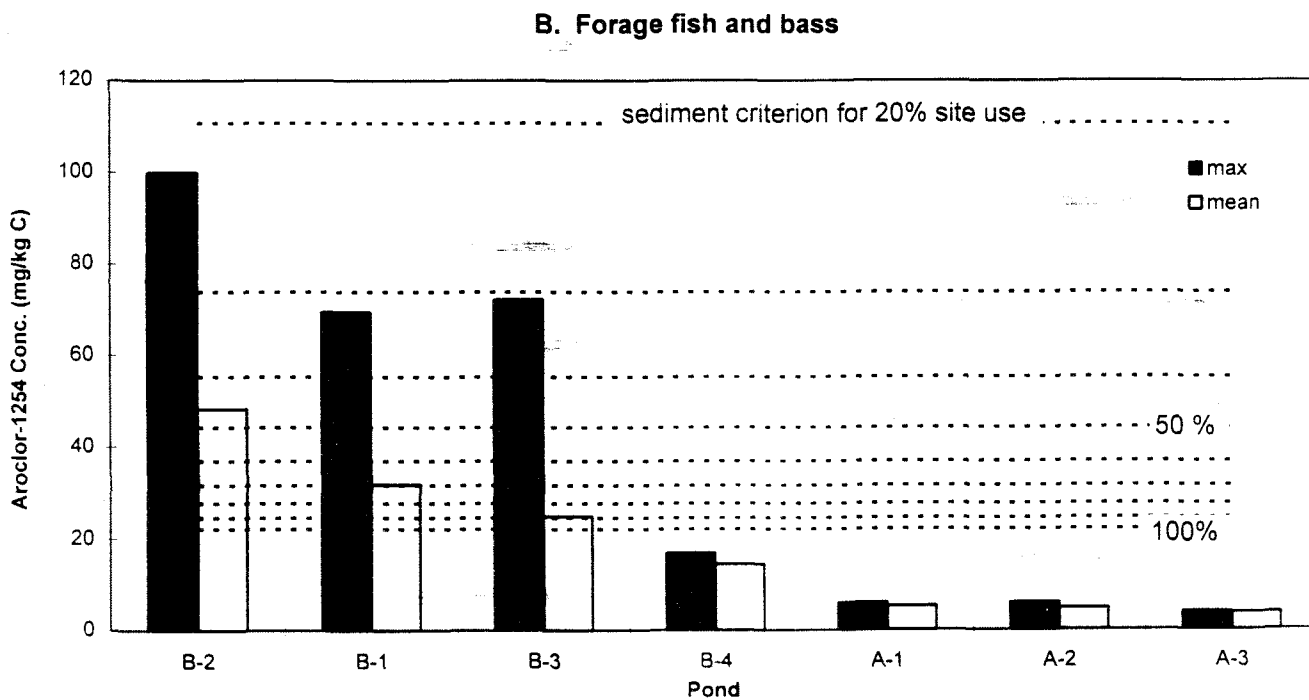
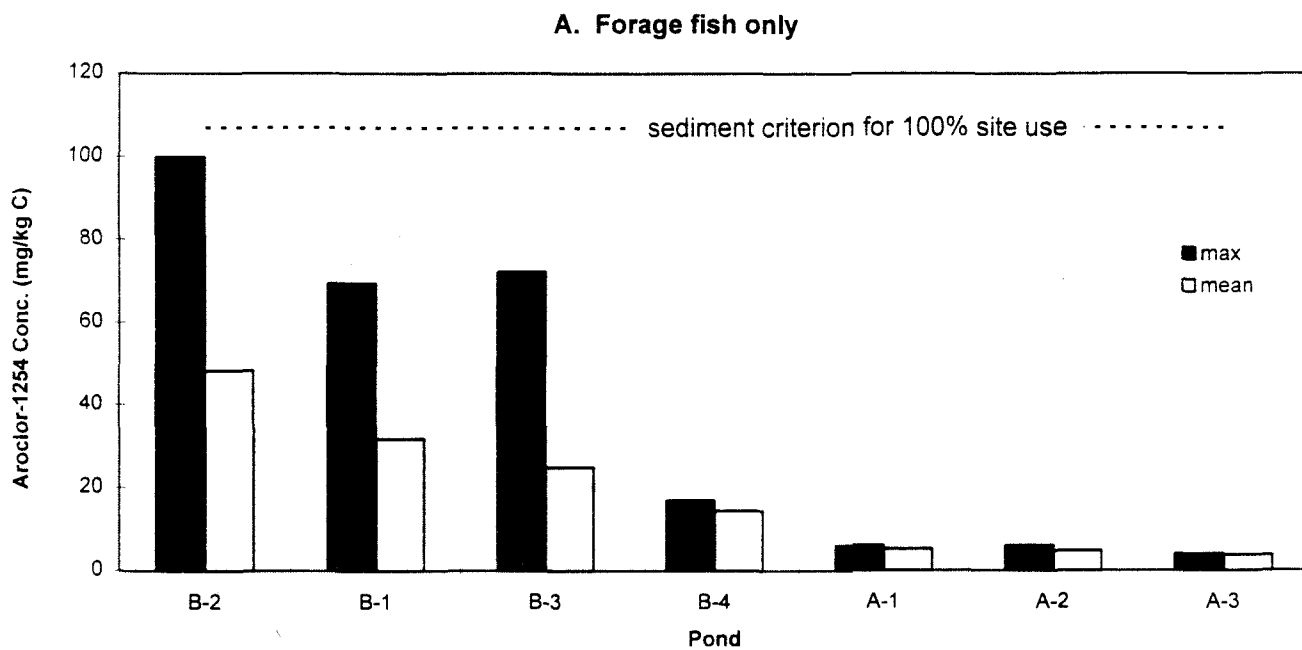


Figure N5-16
Frequency Distribution for Concentrations of Chromium and Lead in
Small Mammals from Upper Walnut Creek

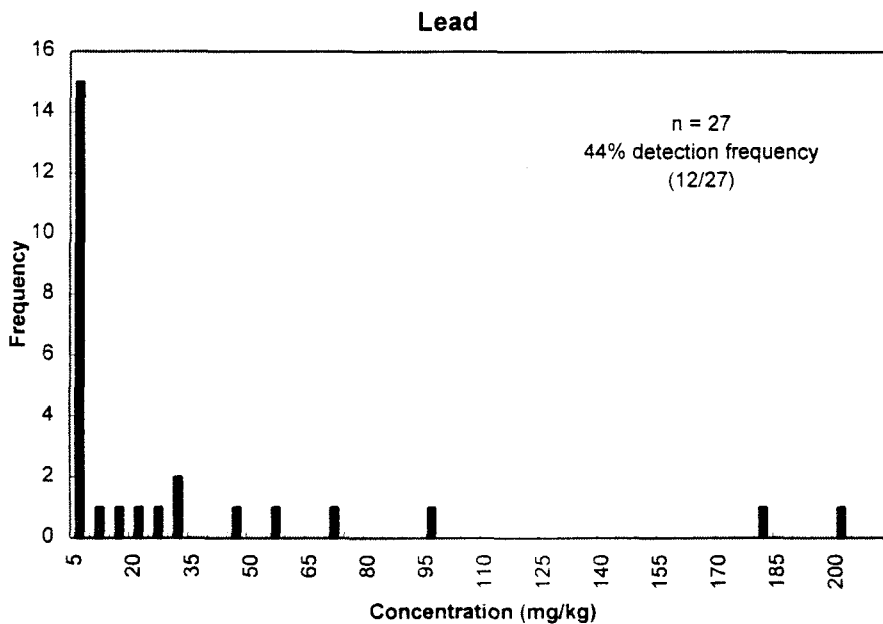
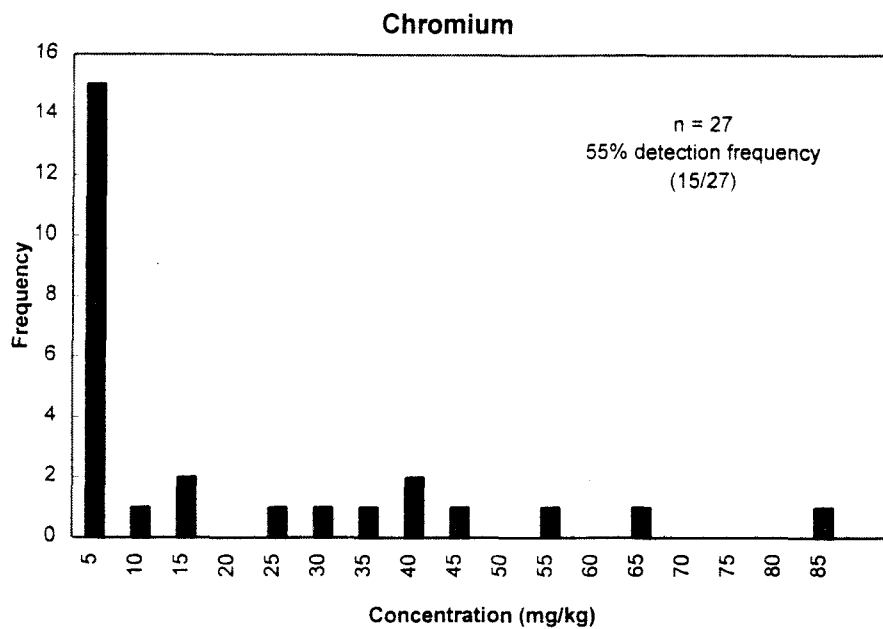


Figure N5-17

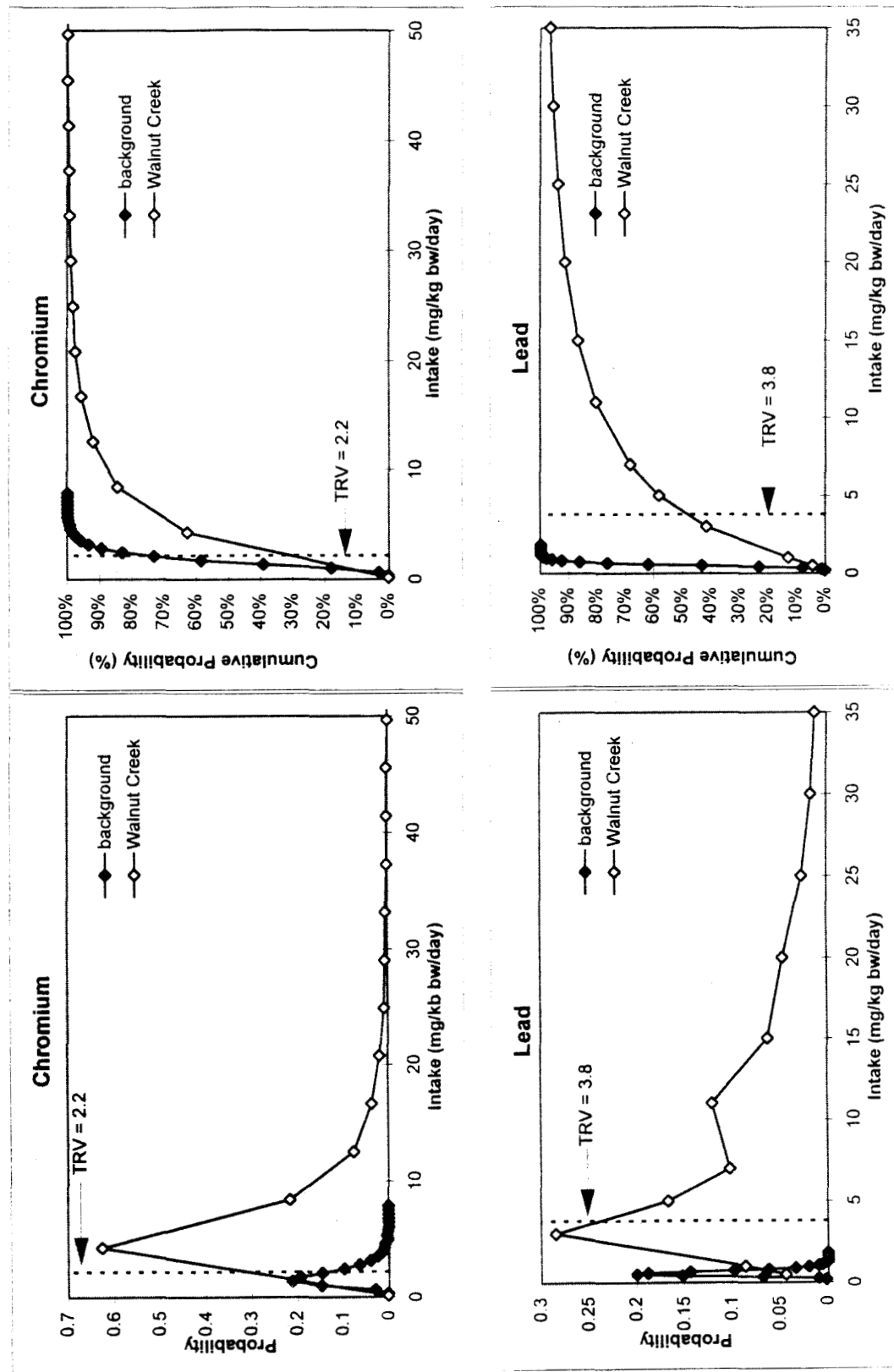
¹Intakes estimated from small mammal data; simulations conducted assuming lognormal distribution of data (500 iterations)

Figure N5-19
HQs of Silver in Sediments of B-Ponds

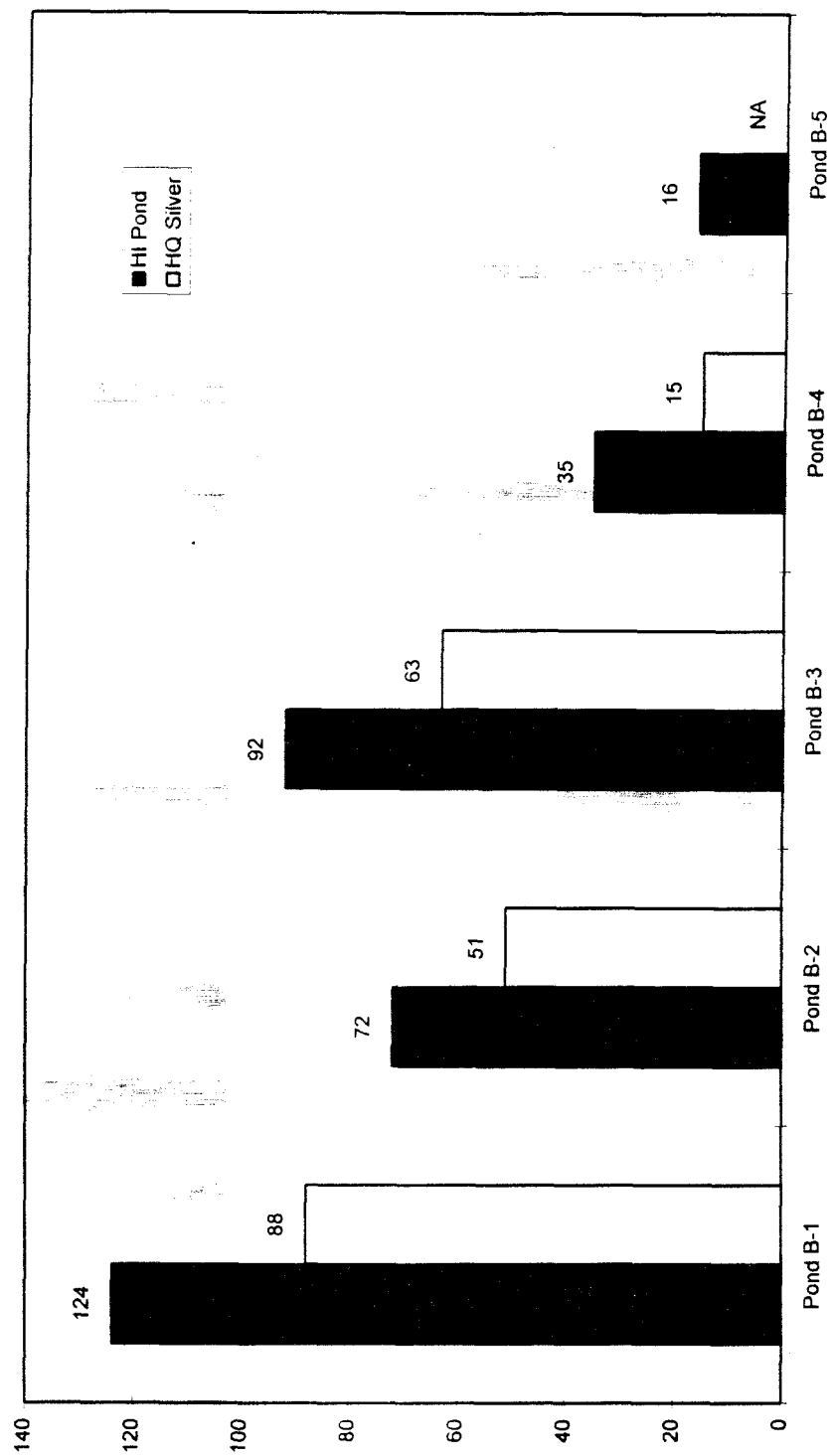


Figure N5-21
Radionuclide Concentrations in Small Mammal Tissue

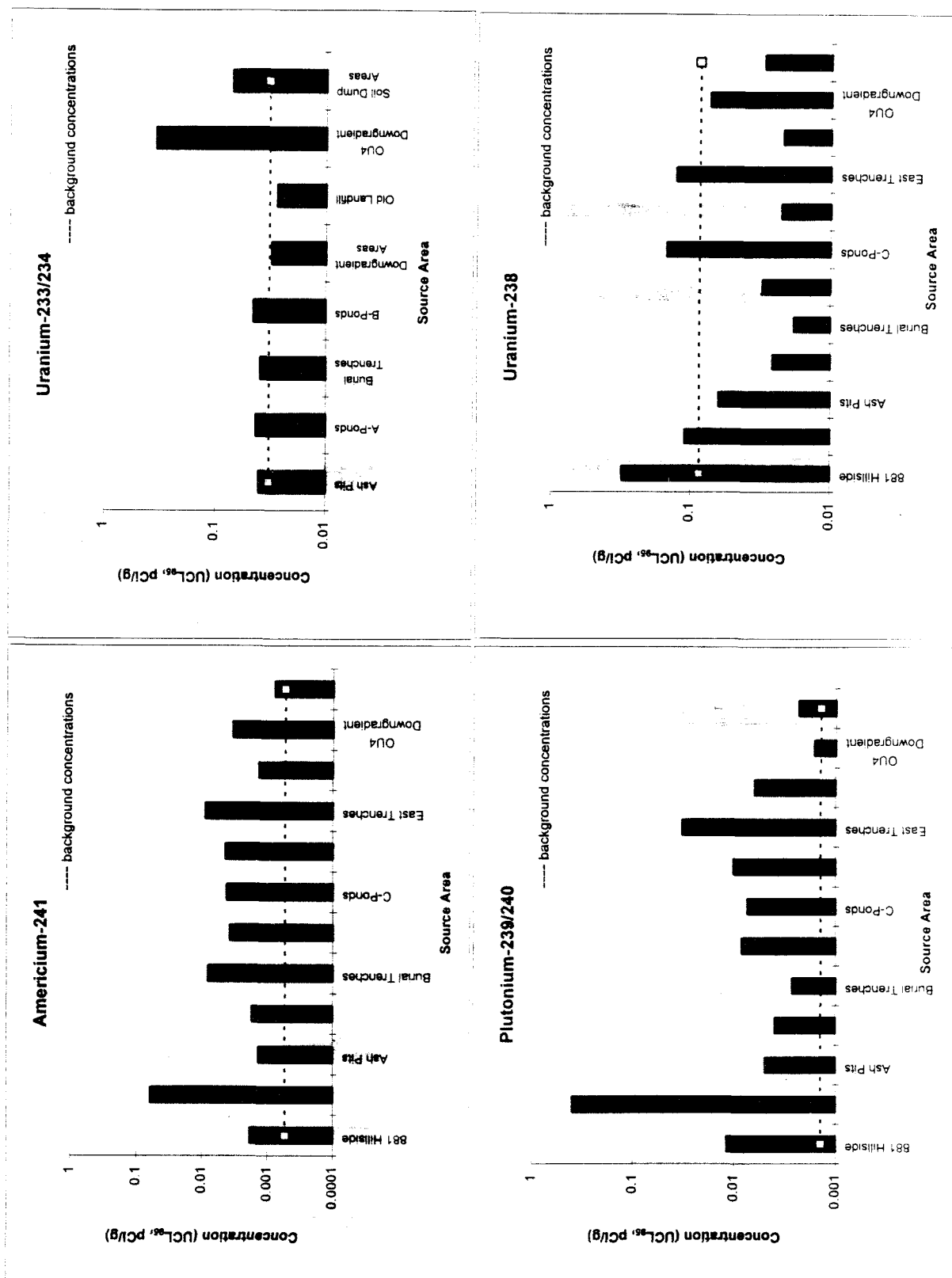


Figure N5-22
Radionuclide Concentrations in Vegetation Tissue

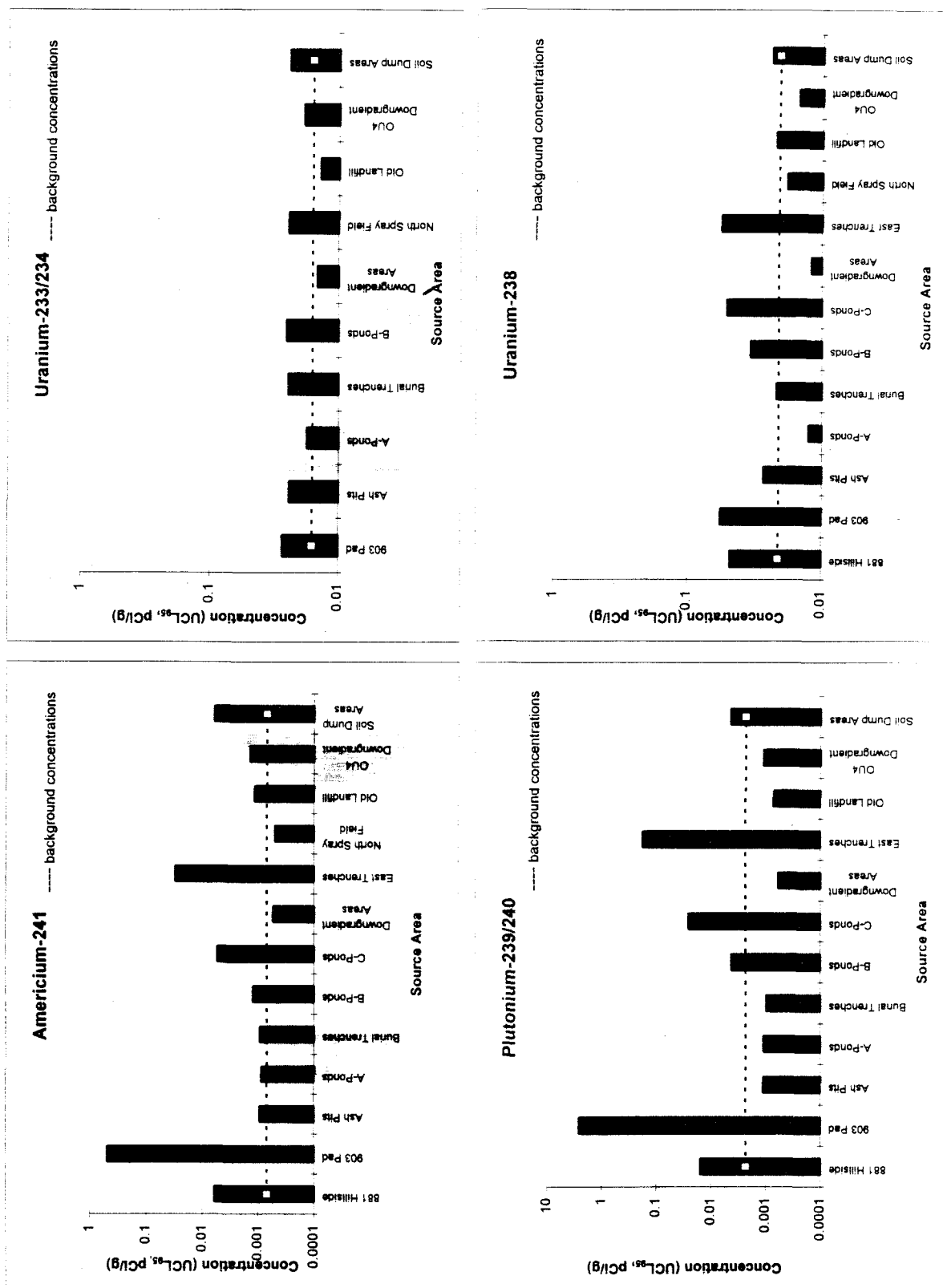
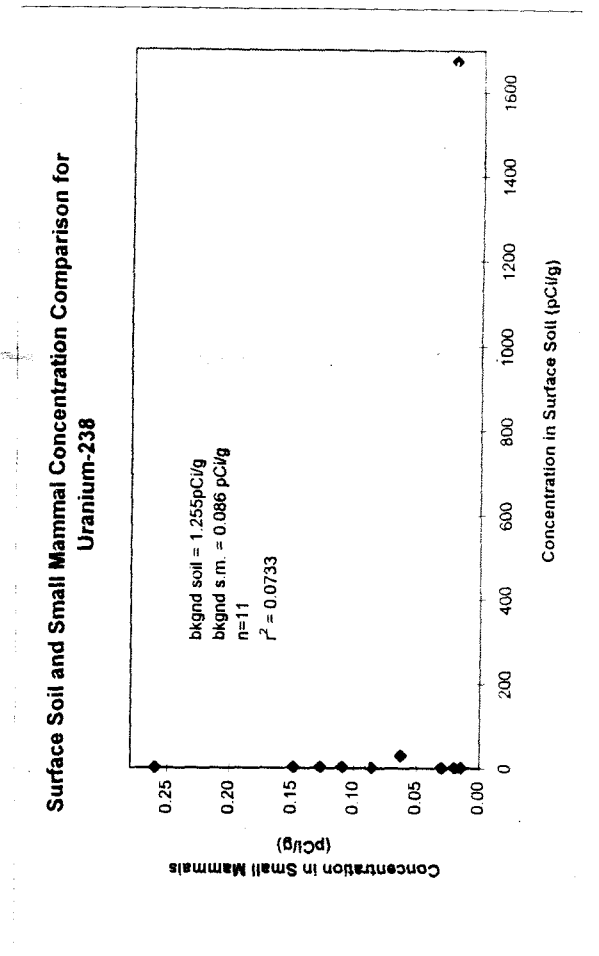
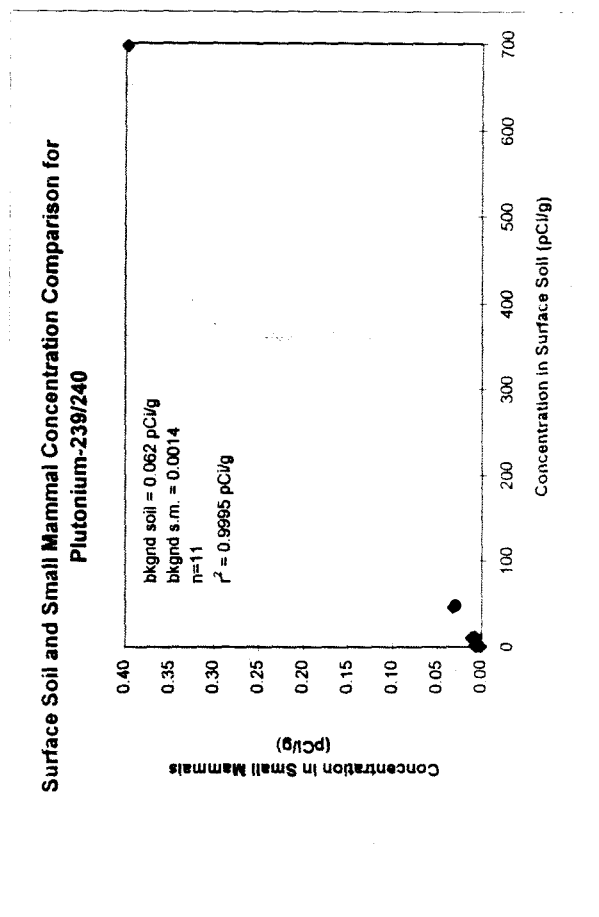
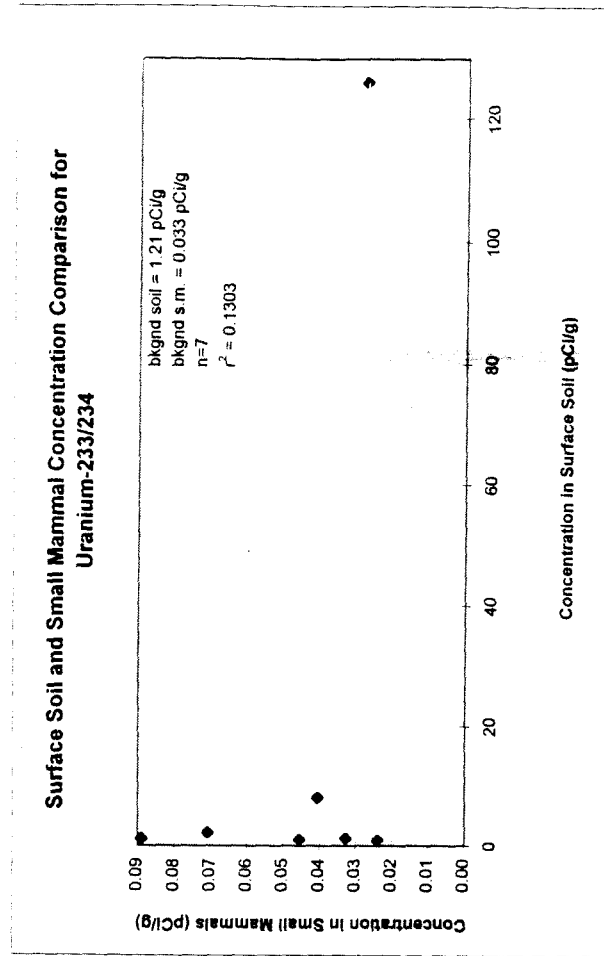
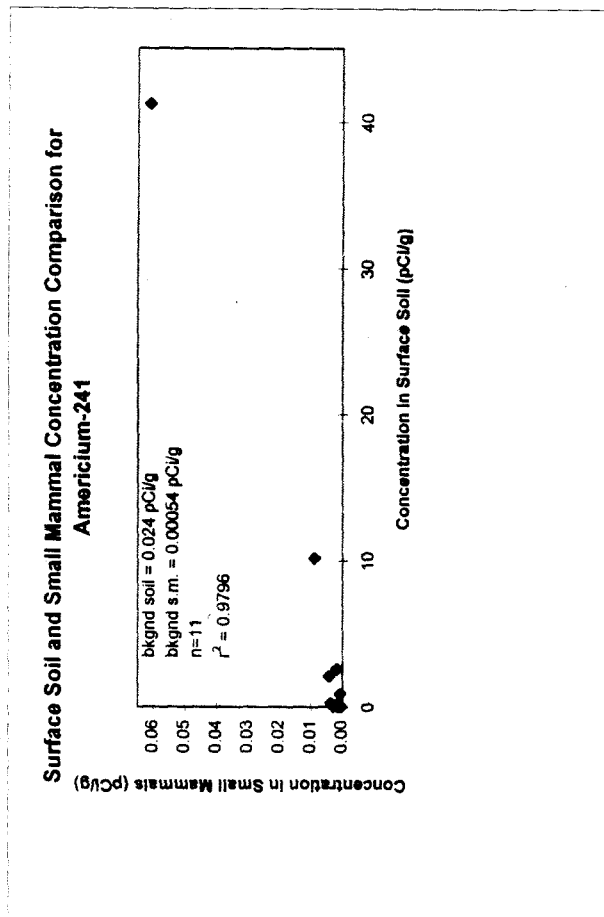


Figure N5-23
Radionuclide Concentrations in Soils vs. Small Mammal Tissue



N6. Conclusions

As described in Section N1, the Walnut Creek and Woman Creek ERAs were conducted to integrate results of RFI/RI from several OUs and assess ecological risk for sources in each watershed. The ERA was performed using data available from abiotic investigations for each OU, biological data collected during RFI/RI field activities, and other data available from ongoing monitoring programs at RFETS.

The primary focus of the ERA was assessment of the potential toxicity of exposures to PCOCs. PCOCs are environmental contaminants identified as a result of sampling and analysis for each RFI/RI. This information was then used to identify chemicals for which exposure analysis was conducted. The analysis was conducted in two phases. A preliminary risk screen was performed for more than 150 PCOCs to identify those that were present at potentially ecotoxic concentrations (Section N3). Screening-level assumptions were adopted to minimize the chance of underestimating risk from a given PCOC. The result of the preliminary risk screen was a list of chemicals, ECOCs, for which potential risk was identified.

The potential risk from exposure to ECOCs was further characterized for key receptor groups. The approach and methods for risk characterization were described in a problem formulation step (Section N4) designed to be consistent with EPA guidance on conducting ERAs (EPA 1994). However, in contrast to the EPA guidance, risk characterization was performed using existing data and toxicity information.

Risk characterization was largely conducted without the benefit of sampling and analysis specifically designed to evaluate effects of ECOCs. However, data were available on concentrations (activities) of metals, radionuclides, and certain organic chemicals (pesticides and PCBs) in aquatic and terrestrial biota in each OU. These data were reliable indicators of exposure and collected to evaluate exposure of upper level consumers to chemicals accumulated in forage or prey (Suter 1993). The main sources of uncertainty and risks to key ecological receptors are summarized in the following sections. Risks are also summarized by watershed, receptor group, ECOC, and ERA source areas in Tables N6-1 and N6-2.

N6.1 Summary of Main Sources of Uncertainty

Many sources of uncertainty are associated with ecological risk assessments or other environmental investigations. Suter *et al.* (1987) identify three main categories of uncertainty sources:

- The fundamentally stochastic (random) nature of the environment
- Incomplete knowledge of the system under study
- Uncertainty associated with execution of the study

The stochastic variability of nature can be quantified and characterized but not reduced, because it is a fundamental property of the system. Some aspects of ecological systems are predictable at some level but the components that are amenable to measurement often have a significant amount of random variability associated with them. Variability within a data set can be reduced by narrowing the scope of sampling to include items of similar qualities, such as collecting only female mice of a certain age and weight. However, the general applicability of the results is proportionately narrowed.

The second source of uncertainty refers to scientific ignorance of the system under study. This source is theoretically reducible, but only at the considerable cost of exhaustive sampling or experimental manipulation. The goal of the RFI/RI and associated risk assessments is not to eliminate uncertainty. Rather, the uncertainty should be characterized in a way that allows it to be used in making informed risk management decisions (EPA 1988a). This type of uncertainty has traditionally been countered by application of conservative assumptions, but this practice can lead to inconsistent estimation of risk, take accurate estimates of uncertainty out of the decision process, and generate "false positives" (Paustenbauch 1990). Nevertheless, assumptions were required in the exposure analyses and toxicity assessments (development of TRVs) because of lack of more accurate or site-specific information. Therefore, where needed, assumptions were conservative to ensure all exposure and risk estimates were biased in one direction and the chance of underestimating risk was minimized (EPA 1994).

The third source of uncertainty involves execution of data collection and analysis. This source of uncertainty includes inappropriate sampling locations, inaccurate or inconsistent sample collection methods, and data recording errors. This type of uncertainty should be addressed in quality assurance plans and site audits. Sampling for the RFETS ERAs was performed in accordance with standard operating procedures for collection of ecological data at the Rocky Flats Plant (EG&G, 1991), and field audits were conducted by independent EG&G and DOE contractors. As noted in Section N1, IAG schedules for individual RFI/RI did not incorporate adequate time for identification of ECOCs prior to biological field investigations. Thus, data on specific effects of many ECOCs was not available.

Biological tissues samples were collected and analyzed for specific contaminants such as metals, radionuclides, and PCBs. Chemical concentrations in tissues are generally the most reliable indicator of exposure for chemicals, such as these, that

are not rapidly metabolized (Suter 1993). The original IAG schedules also did not allow time to monitor natural variation of ecological communities over time. Such data are necessary to determine whether apparent contaminant effects on populations or communities are significant or are within natural variation. However, such data are rarely available for hazardous waste sites and ecological effects are extrapolated from surrogate measures or short-term such as toxicity tests. Toxicity tests were conducted at RFETS for surface water and sediments but not for soils.

Specific sources of uncertainty, assumptions, and potential effects on interpretation of results are summarized in Table N6-3.

N6.2 Summary of Risks to Aquatic Life

The preliminary risk screen was based on comparisons of chemical concentrations in sediments and surface water to TRVs derived from the literature or calculated using methods recommended by EPA (EPA 1992a). The screen identified several ECOCs in sediments but none for surface water. Sediment ECOCs included volatile and semivolatile organics, PCBs, and metals.

The magnitude of sediment HQ and HI values for some sites in Walnut Creek suggested a high level of toxicity to benthic organisms, especially in the A- and B-series ponds furthest upstream and closest to the IA of RFETS. HQs exceeded 100 for some chemicals at these sites (Figure N5-5). PAHs were the main contributors to risk estimates at most sites in Walnut Creek, accounting for 90 percent or more of the HI in Ponds A-1 and B-1 (Figure N5-5). Risk estimates were much lower in the Woman Creek watershed where HIs were below 3; no HQ exceeded 2.6. PAHs were also main contributors to risk estimates in Woman Creek.

The risk levels predicted by the HQ and HI calculations were verified using results of sediment toxicity tests and site data on benthic community structure. If estimates of potential toxicity (i.e., TRVs) and exposures were relatively accurate, then the extremely wide range of HI and HQ values should correspond to varying levels of toxicity to test organisms and impacts on benthic communities. Physical stress such as fluctuating water levels and the presence of organisms in upper trophic levels (e.g., fish) represent confounding factors in this analysis. However, if toxicity is an important factor in controlling benthic community structure, then results should indicate some level of correlation between predicted toxicity (i.e., HIs or HQs) and level of impacts.

Correlations were evaluated using cluster analysis and regression methods. Cluster analyses (Ludwig and Reynolds 1988) were conducted to determine whether groups of sites with similar community composition (e.g., total organism density and

species richness) also had similar HIs or HQs. Regression methods (Sokal and Rohlf 1968) were used to estimate whether the proportion of variation in community structure could be explained by differences in HIs.

Results indicate that predicted toxicity accounts for some of the variation in community composition, but other factors are clearly important. Groups that were identified by cluster analysis based on density, richness, and pollution tolerance were not similar to those identified when the same analysis was conducted using HIs. However, HI did account for about 50 percent of the variation in rank order of ponds with respect to richness (Table N5-6). Results of sediment toxicity testing did not indicate significant toxicity in any of the ponds except Pond B-2, which did not have the highest HIs (Table N5-5).

These results suggest that although toxicity tests do not show robust toxicity, effects of sediment contamination may be manifested in the benthic community structure of the detention ponds. However, other factors such as size, fluctuating water levels, and the presence or absence of upper trophic levels are also important. Potential toxicity of sediment contaminants, particularly PAHs, may be important factors in limiting aquatic communities if physical stress was reduced through a change in management of the ponds.

It should be noted that the ponds were constructed to minimize offsite transport of contaminants, especially radionuclides, in sediments and surface water. The presence of PAHs and metals in sediments are, in part, a result of runoff from industrial areas and input from the wastewater treatment plant. The fact that sediment contaminant concentrations decrease dramatically with distance downstream indicates that the ponds are effective in attenuating offsite transport of sediment-bound contaminants.

N6.3 Summary of Risks to Aquatic-Feeding Birds

Sediment contamination may also affect wildlife that feed in contaminated areas. ECOCs identified for aquatic-feeding wildlife included PCBs (Aroclor-1254), DBP, and mercury. Great blue herons and mallards were identified as representative receptors because birds are more sensitive to many contaminants than are mammals.

Aroclor-1254 was detected in sediments of the A- and B-series ponds with the highest concentrations in Ponds B-1 and B-2. Available data on PCB content of aquatic biota indicated negligible levels for birds feeding on fish, amphibians, or invertebrates from the ponds. However, biological tissue data were not available to evaluate the potential risk from all the ponds for which PCBs were detected in sediments. Therefore, site-specific data on uptake of PCBs by aquatic species were

used to estimate the maximum concentration in sediments that would ultimately result in exposures of herons and mallards that are equal to or less than the TRV. Estimates were based on the organic carbon content of sediments and calculated for a range of levels of site use by the birds.

Risk estimates also accounted for the effects of food chain length on biomagnification. Accumulation of PCBs in upper level consumers is proportional to the length of the food chain through which PCBs are transferred from sediments to top consumers (Rasmussen *et al.* 1990). Calculations were made for two hypothetical food chains: (1) one in which a species such as fathead minnows that feed primarily on zooplankton and algae is the primary prey of aquatic-feeding birds and (2) one in which the main food source is a piscivorous species such as largemouth bass.

Results indicate that risks to herons or mallards are negligible if they feed on fish or invertebrates from lower trophic levels. However, herons may experience toxic exposures if they feed on upper level consumers from Ponds B-1, B-2, or B-3 more than about 40 percent of the time (Figure N5-12). The communities in these ponds currently lack the upper trophic levels, but possible future introduction of predaceous fish or other upper level consumers could result in increased exposure to aquatic birds feeding there. The sediment criteria calculated for evaluating risk can also be used by risk managers in making decisions concerning management of pond sediments.

N6.4 Summary of Risks to Terrestrial-Feeding Raptors

As noted in Section 4.3, chromium, lead, mercury, and vanadium were detected in terrestrial arthropods from OU2 and small mammals from OU4 and OU6 source areas (OU4/6 area) at concentrations that could be toxic to raptors feeding extensively in the areas. American kestrels were selected to represent ecological receptors because they have relatively small home ranges and are known to breed at RFETS.

The preliminary risk estimate for chromium in terrestrial arthropods from OU2 was based on the maximum detected concentration from the East Trenches source area. Chromium concentrations in terrestrial arthropods from the 903 Pad area were estimated based on data from the East Trenches. Thus, data were inadequate to accurately estimate exposures. However, review of the OU2 data suggests that the maximum concentration was anomalously high and its use overestimates risk. The mean chromium concentration in OU2 soils was not elevated compared to background, and chromium was included in the PCOCs because of two samples that exceeded the background UTL_{99/99}. The OU2 source areas represent a small

portion of the mesic and xeric mixed grassland habitat type at RFETS. Thus, exposure to chromium in OU2 does not appear to represent a significant ecological risk to kestrels given the low magnitude of the exposures, probable overestimate of exposure, and relatively small area involved.

Preliminary risk estimates indicated that chromium, lead, mercury, and vanadium could also present a risk to raptors feeding extensively in the areas around the A- and B-series ponds. Review of data revealed that vanadium and mercury were detected with low frequency and at relatively low concentrations and probably do not represent an ecological risk. However, chromium and mercury concentrations were consistently elevated in small mammal samples collected from the pond margins. The source of the elevated concentrations in small mammals is not clear because neither metal was consistently elevated in soils or dry sediments. They were both included in the PCOCs because of samples that exceeded the UTL_{99/99} for soils and sediments. Few small mammals collected from sites further from the ponds contained detectable quantities of either metal.

Probabilistic exposure estimates indicate that kestrels feeding primarily on small mammals in the OU4/6 areas are likely to ingest chromium and lead at rates that exceed background intakes and TRVs. These estimates must be considered conservative because they assume that kestrels feed only on small mammals and small mammal samples from the pond areas are probably over-represented in the data set. Further sampling would be required to more accurately evaluate exposures and identify the source of chromium and lead in small mammals.

N6.5 Summary of Risks to Small Mammals

Preliminary risk estimates indicated little risk to small mammals from ingestion of contaminants in RFETS source areas. Barium and selenium were identified as ECOCs in the (OU6) North Spray Field and OU7 Downgradient source areas, respectively. Both metals were detected at potentially ecotoxic concentrations in vegetation. Risk was evaluated for populations of more common species and individuals of PMJM, a species of special concern at RFETS.

Exposure to barium in the North Spray Field appears to represent little risk to small mammal populations at RFETS. The North Spray Field includes about 0.64 percent of the mesic mixed grassland habitat type in the Walnut Creek watershed and does not appear to contain any resources that are not common in other grassland areas of the site. Thus, a negligible proportion of populations of common grassland species are likely to be affected. However, this source area does include areas identified as potential habitat for PMJM and exposure of individuals of this species is of concern.

The HQ for barium ingestion from the site was 1.05. The TRV for barium was based on concentrations that produced hypertension in laboratory rats (Perry *et al.* 1983 as cited in Opresko *et al.* 1994). The concentration on which the NOAEL was based was the maximum dose in the study and did not affect growth or food or water consumption in experimental animals. Therefore, the level of risk associated with exceeding the TRV is unclear. Thus, the barium concentration in vegetation in this source area may produce some adverse effects in individual animals, but the potential for long-term effects on growth or reproduction is unclear, but appears to be minimal.

The source of selenium in vegetation from the OU7 downgradient area is not clear. This area was not subject to spray evaporation of water from the landfill pond (DOE 1995e). The vegetation samples from the area may have included selenium accumulators (such as *Astragalus* sp.) that are common at RFETS. The area represents an insignificant proportion of the total mesic grassland habitat RFETS. However, the source area is located within areas identified as probable habitat for PMJM.

The TRV for selenium was based on intakes calculated for background areas of RFETS (0.317 mg/kg/day) because it exceeded the literature-based ecotoxicological benchmark (0.075 mg/kg/day). This suggests that small mammals inhabiting RFETS may be adapted to high ambient concentrations of selenium that are common in semi-arid areas of the Rocky Mountain west. However, intakes from the OU7 area are more than twice those estimated for background areas and may represent a risk to individuals that spend all of their time there.

The presence of PMJM in the OU7 Downgradient area has not been confirmed. However, confirmed captures have been recorded for areas approximately 2.2 km to the east in riparian habitat along Walnut Creek. The OU7 Downgradient area does not include the well-developed riparian vegetation of these other areas; therefore, it is probably not critical habitat for the PMJM. However, it is possible that individuals dispersing from currently inhabited areas could contact vegetation and soils in the OU7 Downgradient area.

N6.6 Summary of Risks to Vegetation Communities

HQs for several inorganic contaminants and metals exceeded 1 in subsurface soils and sediments in various source areas. The highest HQ for soils was due to nitrates in the OU7 Downgradient area and for silver in sediments of the B-ponds. The risks associated with the PCOCs are uncertain. As noted previously, no obvious areas of vegetation stress were observed during field investigations. It is possible that concentrations for most ECOC metals in soils are within the range tolerated by

plant species at RFETS. However, the potential phytotoxicity is not known because soil toxicity tests were not conducted during RFI/RIs.

TRVs were not available for most organic soil or sediment PCOCs. HQs were well below 1 for organic PCOCs for which TRVs were available. However, as with metals, the potential phytotoxicity of most organic PCOCs was not quantified with plant toxicity tests.

N6.7 Summary of Risks from Radionuclides

Transuranic radionuclides were identified as PCOCs for most OUs. The ECOC screen indicated relatively few areas with radionuclide concentrations (activities) in soils that exceeded TRVs. Plutonium-239/240 and americium-241 concentrations in soils exceeded TRVs in two locations in the 903 Pad source areas, and uranium-233/234 and uranium-238 concentrations in soils of the Old Landfill exceeded TRVs at two locations. Radionuclides were also elevated in vegetation and small mammals collected from ERA source areas.

The potential risks from radionuclide uptake by biota were evaluated by calculating the internal radiological dose and comparing it to the TRV. The TRV was based on a benchmark value of 0.1 rad/day, which was identified by IAEA (1992) as protective of biological receptors. Results indicated that maximum radionuclide concentrations measured in small mammal resulted in dose rates at least 1,000 times less than the TRV. The potential uptake by predators was also evaluated and indicated that risks to predators were also not significant. Thus, although abiotic media and biota contain elevated concentrations of transuranic radionuclides, risks of adverse effects appear to be negligible.

CHAPTER N6

TABLES

Table N6-1
Summary of Ecological Risks for Walnut Creek Watershed

Receptor Group	ECOCs	ERA Source Area	Media/Exposure Point	Conclusions
Wide-Ranging Wildlife Aquatic Life	None Metals and Organics in Sediments	Not Applicable OU6 A-Ponds OU6 B-Ponds	Not Applicable Sediments	The Tier 3 ECOC screen did not identify ECOCs Risks are primarily due to PAHs in sediments. However, no toxicity was detected in sediment toxicity tests with <i>Hyalella azteca</i> . Importance of sediment contamination is unclear but does not appear to be the to be the primary factor controlling benthic community structure.
Aquatic-Feeding Birds	Aroclor-1254	OU6 A-Ponds OU6 B-Ponds	Pond Sediments	Aroclor-1254 concentrations in sediment exceeded risk-based criteria for ponds B-1, B-2, and B-3 only if top aquatic predators were present. Ponds currently do not support this type of community but could if pond management changed.
	Mercury	OU6 A-Ponds OU6 B-Ponds	Fish Tissue	Mercury was detected in 75% of fish from B-ponds. However, the maximum concentration was detected in B-5, which has the lowest contaminant content. The maximum HQ was 2. Mercury does not appear to represent risk to herons.
	Di-N-butyl phthalate	OU6 A-Ponds OU6 B-Ponds	Sediments	All samples with detectable DBP concentrations were "J" qualified. Only one sample corresponds to an HQ of 2; all other HQs are ≤ 1 . DBP does not appear to represent risk to herons or mallards.
Terrestrial-Feeding Raptors	Chromium	OU2 903 Pad OU2 East Trenches	Terrestrial Arthropods	Mean chromium concentration in soils was not greater than the background mean. No clear contaminant source exists. Chromium is not a risk to the kestrel population at RFETS.
	Chromium, Lead	OU4 Downgradient OU6 A-Ponds OU6 B-Ponds	Small Mammals	Chromium and lead were elevated in small mammals from pond areas. The source is unclear because soils and sediments contain low levels. Risks are possible to individual birds feeding in the area, but effects to RFETS population are minimal.
	Mercury, Vanadium	OU4 Downgradient OU6 A-Ponds OU6 B-Ponds	Small Mammals	Mercury and vanadium were detected at low frequency and some concentrations were "J" qualified. Risks appear to be minimal.
Small Mammals	Plutonium-239/240 Americium-241	OU2 903 Pad OU2 East Trenches	Soils	Radionuclides do not present significant risk to terrestrial receptors. Maximum tissue concentrations do not result in dose rates that exceed the TRV (0.1 rad/day)
	Barium	OU6 North Spray Field	Vegetation	The barium HQ of 1.05 indicates that exposures are very close to the NOAEL. Risks to small mammal populations are negligible. Some individual jumping mice might be exposed, but adverse effects would be minimal.
	Selenium	OU7 Downgradient	Vegetation	Selenium exposure exists in a small area but includes habitat for jumping mouse. The source of selenium is not clear. Levels in vegetation were twice that of background. Possible adverse effects to individuals exist, but population effects were negligible due to the small area.
Vegetation	Metals and Organics	Most Source Areas	Soils, Sediments	Nitrates in OU7 and OU4, and silver in B-ponds have the highest risk estimates. However, ecological risk is unclear because vegetation in these areas does not appear stressed.

Table N6-2
Summary of Ecological Risks for Woman Creek Watershed

Receptor Group	ECOCs	ERA Source Area	Media/Exposure Point	Conclusions
Wide-Ranging Wildlife Aquatic Life	None Metals and organics in sediments	Not Applicable OU2 903 Pad OU5 C-Ponds OU5 Old Landfill	Not Applicable Sediments	The Tier 3 ECOC screen did not identify ECOCs. Risks are primarily due to PAHs in sediments. However, no toxicity was detected in sediment toxicity tests with <i>Hyalella</i> <i>azteca</i> . The importance of sediment contamination is unclear but does not appear to be the primary factor controlling benthic community structure.
Aquatic-Feeding Birds	Aroclor-1254 Mercury Antimony	OU5 C-Ponds OU5 Old Landfill OU5 C-Ponds OU5 Old Landfill	Sediments of SID Fish Tissue Sediments	Aroclor-1254 concentrations in sediment did not exceed risk based criteria developed for sediment at RFETS. Mercury was detected in 2 of 24 fish from C-ponds. Mercury was not detected in other fish. Risks are significant only if birds obtain all food from C-1. The screening estimate assumes 100% site use. Actual use is much less because the stream supports a small fish population. Risks were not significant when adjusted for realistic site use factor.
Terrestrial-Feeding Raptors	Chromium	OU2 903 Pad OU2 East Trenches	Terrestrial Arthropods	The mean chromium concentration in soils was not greater than background mean. No clear contaminant source exists. Chromium was not a risk to the kestrel population at RFETS.
Small Mammals	Plutonium-239/240 Americium-241	OU2 903 Pad OU2 East Trenches	Soils	Radionuclides do not present significant risk to terrestrial receptors. Maximum tissue concentrations do not result in dose rates that exceed TRVs (0.1 rad/day).
	Uranium-233/234 Uranium-238	OU5 Old Landfill	Soils	See text for plutonium and americium conclusions.
Vegetation	Metals	Most Source Areas	Soils, Sediments	Soils of Ash Pits contained several metals with HQs >1. The highest HQ (7.9) was for chromium. Ecological risk to vegetation communities is minimal because each of the Ash Pits involves relatively small areas. Sediments of C-ponds contain mercury at concentrations that exceed TRVs for wetland vegetation. However, growth of vegetation in littoral zone appears normal.

Table N6-3
Sources of Uncertainty and Their Potential Effects on Results and Conclusions of the Walnut Creek and Woman Creek ERAs

Source	Effect	Remark
Toxicity Assessment		
1. Lack of specific toxicity information for exposure of Rocky Flats species to COCs	May over- or underestimate critical effects concentrations	This is especially important in assessment of potential toxicity to vegetation and exposure of small mammals to burrow air. Toxicity information is also lacking for other receptors/chemicals. Exposures for all PCOCs were calculated and presented. Toxicity information was derived from open literature; standardized tests were not generally available for non-aquatic species. Data for most sensitive species was used to protect greater number of species. NOELs are derived from LOELs by dividing by 10. This is probably conservative since NOELs are not usually 0.1 of LOELs.
2. Variable endpoints used to set TRVs	Inconsistent estimate of effects	
3. Use most sensitive species in literature to set TRV	May over- or underestimate critical effects concentrations	
4. Estimation of NOEL from other data	May over- or underestimate critical effects concentrations	
Exposure Assessment		
1. Number of samples may not be adequate to estimate exposure	May over- or underestimate exposure if data are not representative of true condition	UCL ₉₅ or maximum concentration was used to estimate exposure. Conservative assumptions were used in estimating uptake of organic chemicals by aquatic and terrestrial biota to minimize chance of underestimating risk.
2. Use data from all soil depths to estimate vegetation and burrow air exposures	May overestimate exposure if highest concentrations are from depths not accessible by roots or small mammals	Depth information was not uniformly available for subsurface soil (borehole samples) data.
3. Tissue analytes identified before contaminants known	Data on chemicals concentration in biological tissue not available for some PCOCs	BCFs and transfer coefficients from the literature were used in modeling uptake of some COCs.
4. Abiotic sampling not designed specifically for ecological risk assessment	Data on chemical concentrations in abiotic media may not represent true exposure point concentrations	The exposure assessment adopted a screening level approach that is based on conservative assumptions and is designed to minimize chance of underestimating exposures.
5. Assume all portions of source areas used equally	May over- or underestimate exposure for a given point in source area	Source area boundaries were chosen to include all potentially contaminated areas. UCL ₉₅ or maximum concentrations were used in exposure estimates to yield conservative exposure estimates.
6. Assume all chemicals in abiotic and biotic sample are bioavailable	May overestimate exposure to radionuclides and metals	Not all contaminants taken up are assimilated. This is especially true for metals which form significant portions of natural rock matrices.
7. Assume equilibrium between VOCs in soil and burrow air	May overestimate concentration of VOCs in burrow air	Burrows are usually not closed systems. Therefore, diluting effect of exchange with ambient air not included in exposure estimate.

Table N6-3
Sources of Uncertainty and Their Potential Effects on Results and Conclusions of the Walnut Creek and Woman Creek ERAs

Source	Effect	Remark
8. Assignment of frequency distributions in simulation modeling	May over- or underestimate probability of exceeding critical value	Mean values are probably not affected, but values in "tails" of distribution may be over- or under-represented.
9. Use of mean ingestion rates, body weights, and home range sizes in simulation modeling	May over- or underestimate probability of exceeding critical value	Means were used because data from literature were not amenable to statistical analysis.
1. Quality of water and sediment toxicity tests	Effects Assessment Lack of confidence in test results Importance of PCOC concentrations exceeding TRVs for vegetation is unvalidated Estimates of exposure and effects uncertain No direct measure of exposure	Prescribed temperature and survival of organisms in controls were not met in some tests.
2. Phytotoxicity tests not conducted		No obvious areas of vegetative stress were observed during field investigations. Some areas with weedy species may indicate stress to community from physical disturbance and may mask chemical stress.
3. Tissue concentrations or biomarkers not available for some EOCs		Specific measures of sublethal physiological stress are needed to evaluate effects of compounds such as PAHs.
4. Tissue concentrations not available for upper level vertebrate consumers		Conventional methods were supplemented by site-specific data on uptake ratios used to estimate uptake.

N7. References

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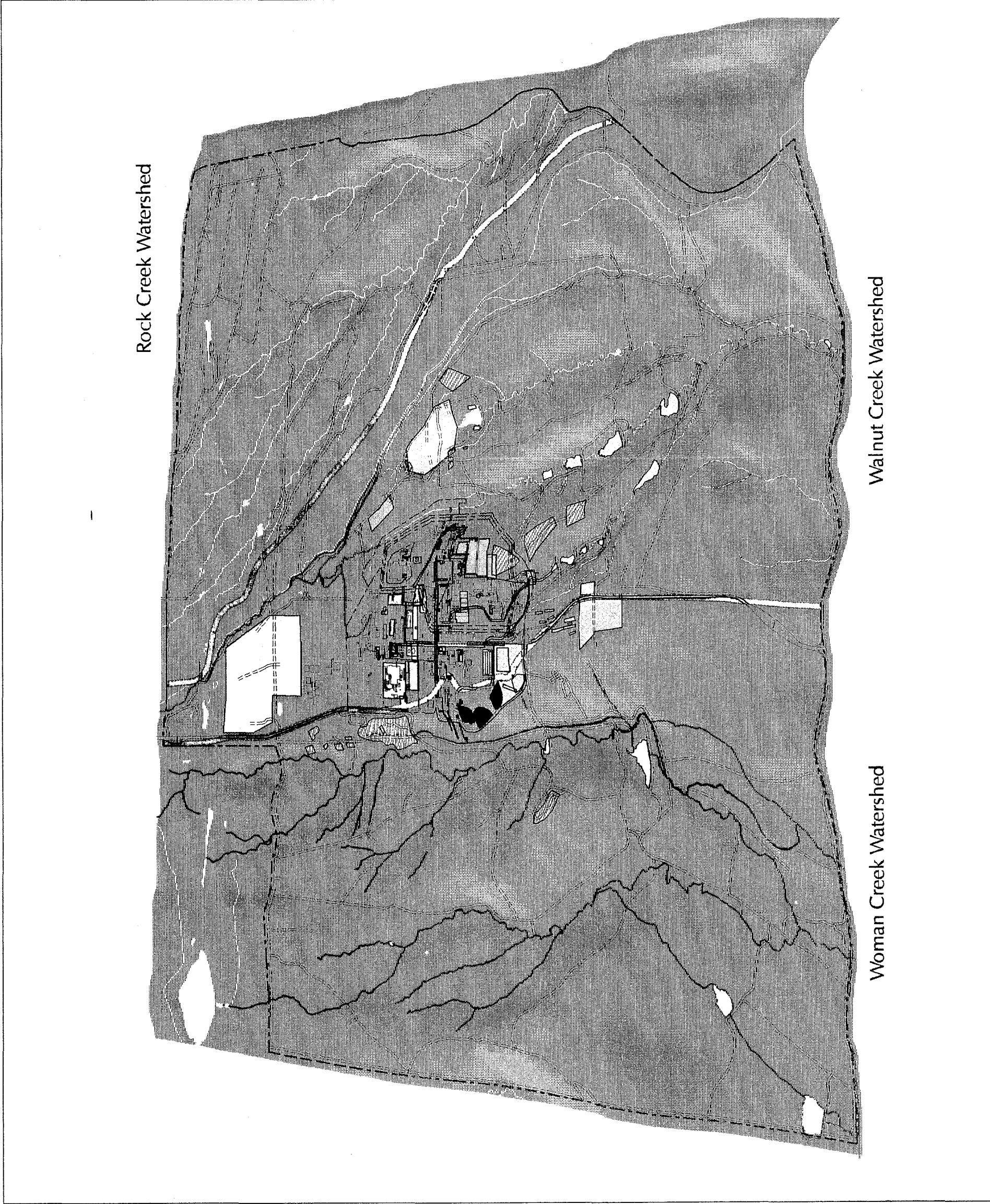
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EXPLANATION

Artificial Fill (latest Recent)

Piney Creek and Post-Piney Creek Alluvium (Recent)

Terrace Alluvium, undivided (late and middle Pleistocene)

Slocum Alluvium (middle Pleistocene)

Verdos Alluvium (early middle Pleistocene)

Rocky Flats Alluvium (early Pleistocene)

Colluvium, undivided (Holocene to middle Pleistocene)

Landslide Deposits (Holocene to middle Pleistocene)

Arapahoe Formation (Upper Cretaceous)

Laramie Formation (Upper Cretaceous)

Fox Hills Sandstone (Upper Cretaceous)

Strike and Dip of Beds

Spring

Mine Shaft

Clast Identification Site

Watershed Boundary

Rock Creek Watershed

Walnut Creek Watershed

Woman Creek Watershed

Central Avenue

Dirt Roads

Canals and Ditches

Security Fences

Rocky Flats Buffer Zone

Lakes and Ponds

Buildings

Modified from: USGS 1994

Scale = 1:20400
1 inch = 1700 feet

Datum: NAD27
Colorado Central Zone
State Plane Coordinate System

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

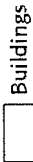
ERAs for Walnut Creek and Woman Creek Watersheds at RFETS

Surficial Geology

EXPLANATION

- Denver clay loam, 2 - 5%
- Denver clay loam, 5 - 9%
- Denver-Kutch clay loam, 5 - 9%
- Denver-Kutch clay loam, 9 - 15%
- Denver-Kutch-Midway clay loam, 9 - 25%
- Englewood clay loam, 0 - 2%
- Englewood clay loam, 2 - 5%
- Flatirons very cobbly sandy loam, 0 - 3%
- Flatirons very stoney sandy loam, 0 - 5%
- Haverson loam, 0 - 3%
- Leyden-Primen-Standley cobbly clay loam, 15 - 50%
- McClave clay loam, 0 - 3%
- Midway clay loam, 9 - 30%
- Nederland very cobbly sandy loam, 15 - 50%
- Nunn clay loam, 0 - 2%
- Nunn clay loam, 2 - 5%
- Pits, gravel
- Sedimentary rock outcrop
- Standley-Nunn gravelly clay loam, 0 - 5%
- Valmont clay loam, 0 - 3%
- Veldkamp-Nederland very cobbly sandy loam, 0 - 3%
- Willowman-Leyden cobbly loam, 9 - 30%
- Yoder Variant-Midway complex, 15 - 60%

- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds



Modified from: Price and Amen 1983

Scale = 1:20400
1 inch = 1700 feet



Datum: NAD27
Colorado Central Zone
State Plane Coordinate System

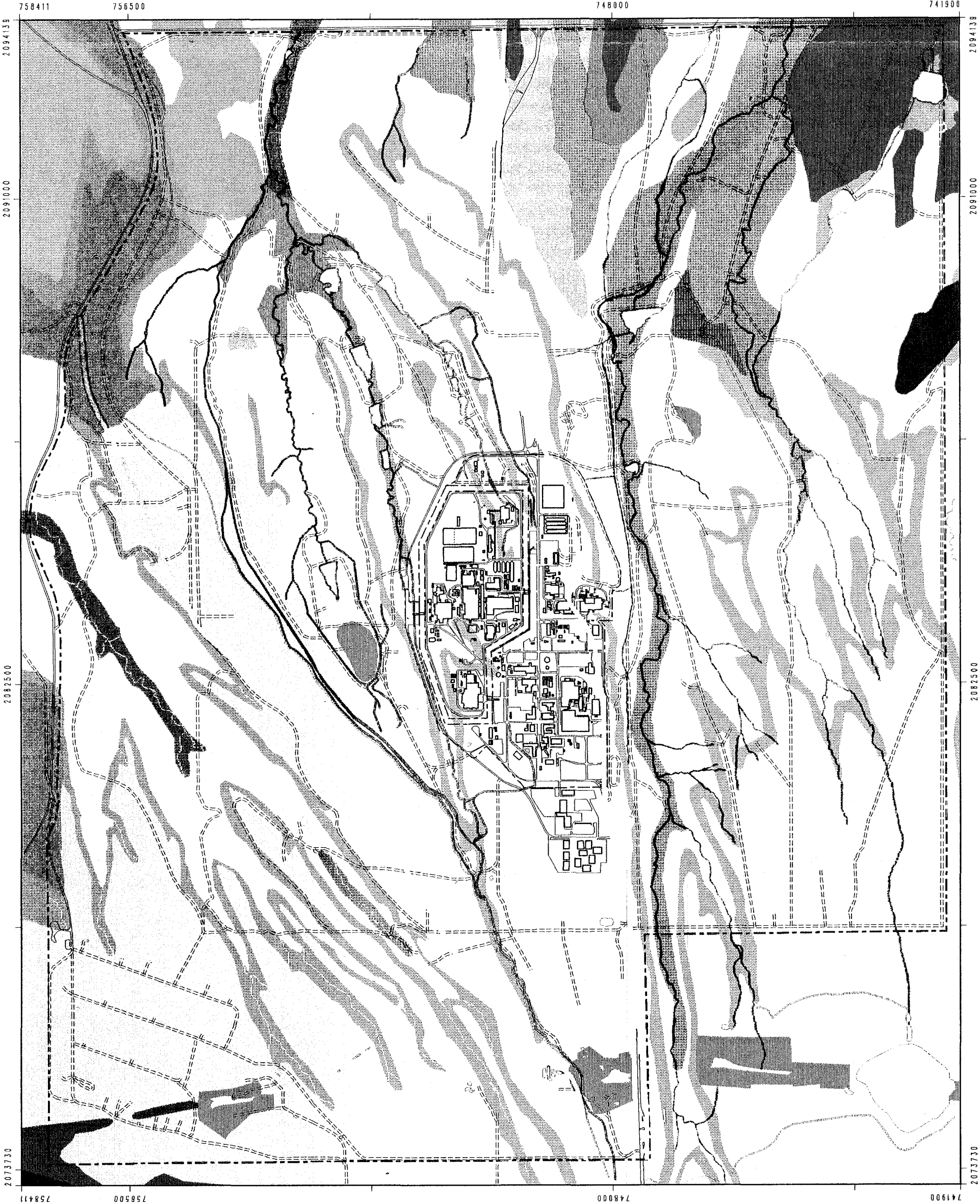
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Golden, Colorado

ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

Soil Types

September 1995

Figure N2-2



EXPLANATION

- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds
- Buildings
- Operable Unit 1
881 Hillside
- Operable Unit 2
903 Pad, Mound, and East Trenches
- Operable Unit 4
Solar Ponds
- Operable Unit 5
Woman Creek
- Operable Unit 6
Walnut Creek
- Operable Unit 7
Present Landfill
- Operable Unit 10
Other Outside Closures
- Operable Unit 11
West Spray Field



U.S. Department of Energy
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Golden, Colorado

ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

Distribution of IHSSs
in
Walnut Creek Watershed

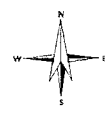
September 1995

Figure N2-3



EXPLANATION

- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds
- Buildings
- Operable Unit 1
881 Hillside
- Operable Unit 2
903 Pad, Mound, and East Trenches
- Operable Unit 4
Solar Ponds
- Operable Unit 5
Woman Creek
- Operable Unit 6
Walnut Creek
- Operable Unit 10
Other Outside Closures
- Operable Unit 11
West Spray Field



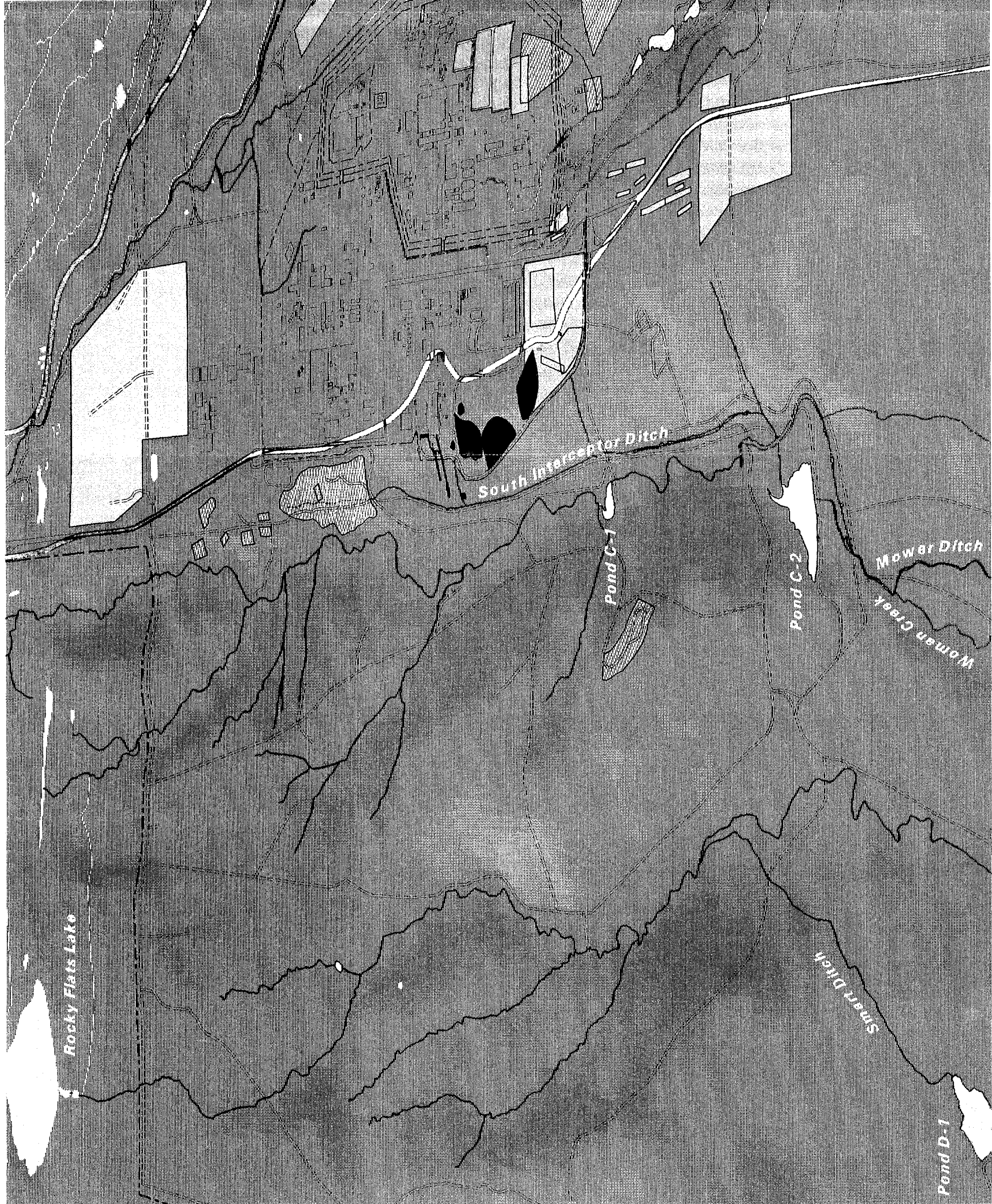
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Golden, Colorado

ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

Distribution of IHSSs
in
Woman Creek Watershed

September 1995

Figure N2-4



EXPLANATION

- Wet Meadow
- Short Marsh
- Tall Marsh
- Riparian Woodland
- Ponderosa Pine Woodland
- Tree Plantings
- Riparian Shrub
- Short Upland Shrub
- Tall Upland Shrub
- Short Grassland
- Mesic Mixed Grassland
- Xeric Mixed Grassland
- Reclaimed Grassland
- Disturbed Area - Annual Grass/Forb
- Disturbed Area - Disturbed/Barren Land
- Disturbed Area - Developed Areas

- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds

- Buildings

Scale = 1 : 20400
1 inch = 1700 feet



Datum: NAD27
Colorado Central Zone
State Plane Coordinate System

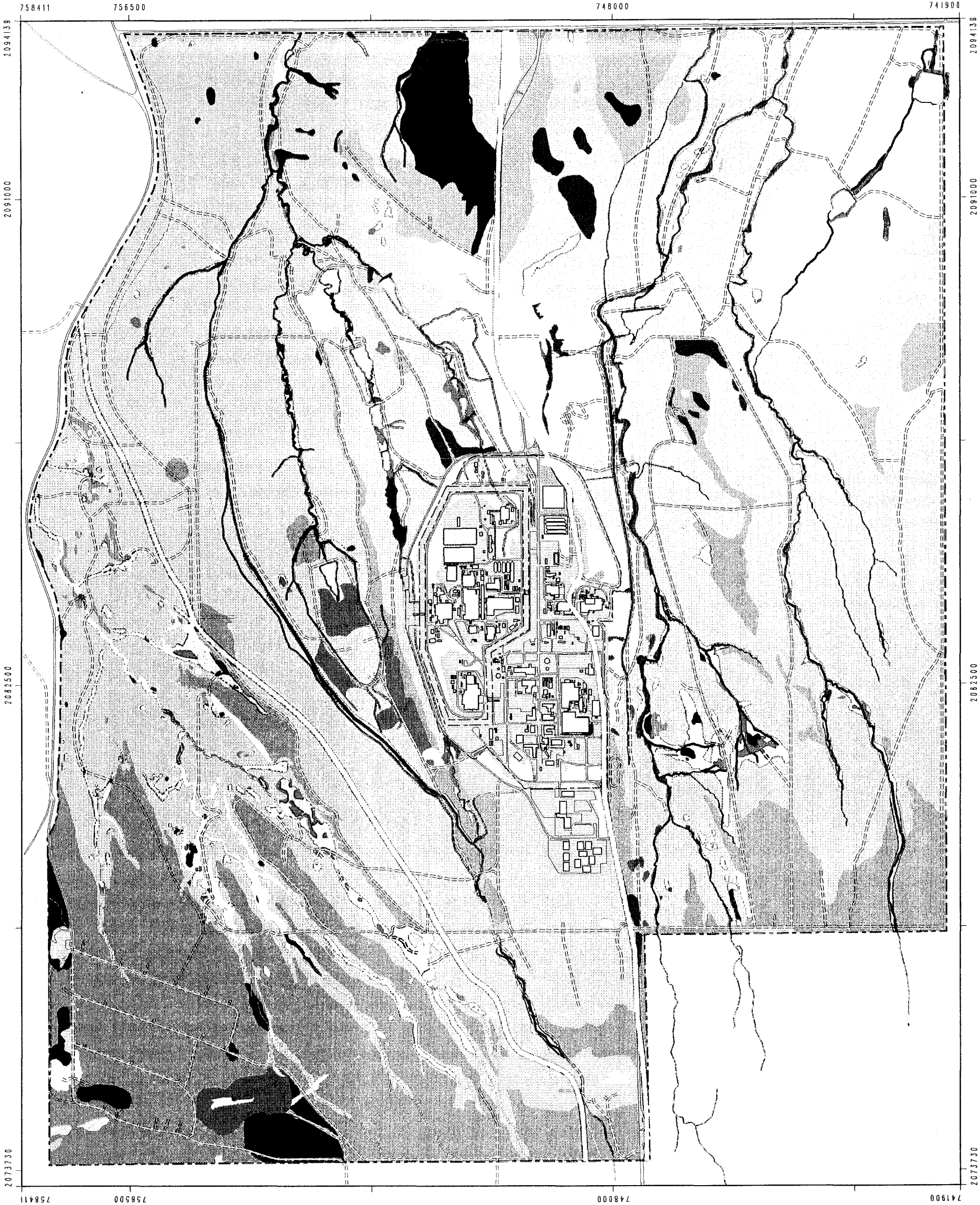
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Golden, Colorado

ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

Vegetation Types

September 1995

Figure N2-5



EXPLANATION

- Wetlands
- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds
- Buildings

Modified from: DOE 1994a



Scale = 1 : 20400
1 inch = 1700 feet



Datum: NAD27
Colorado Central Zone
State Plane Coordinate System

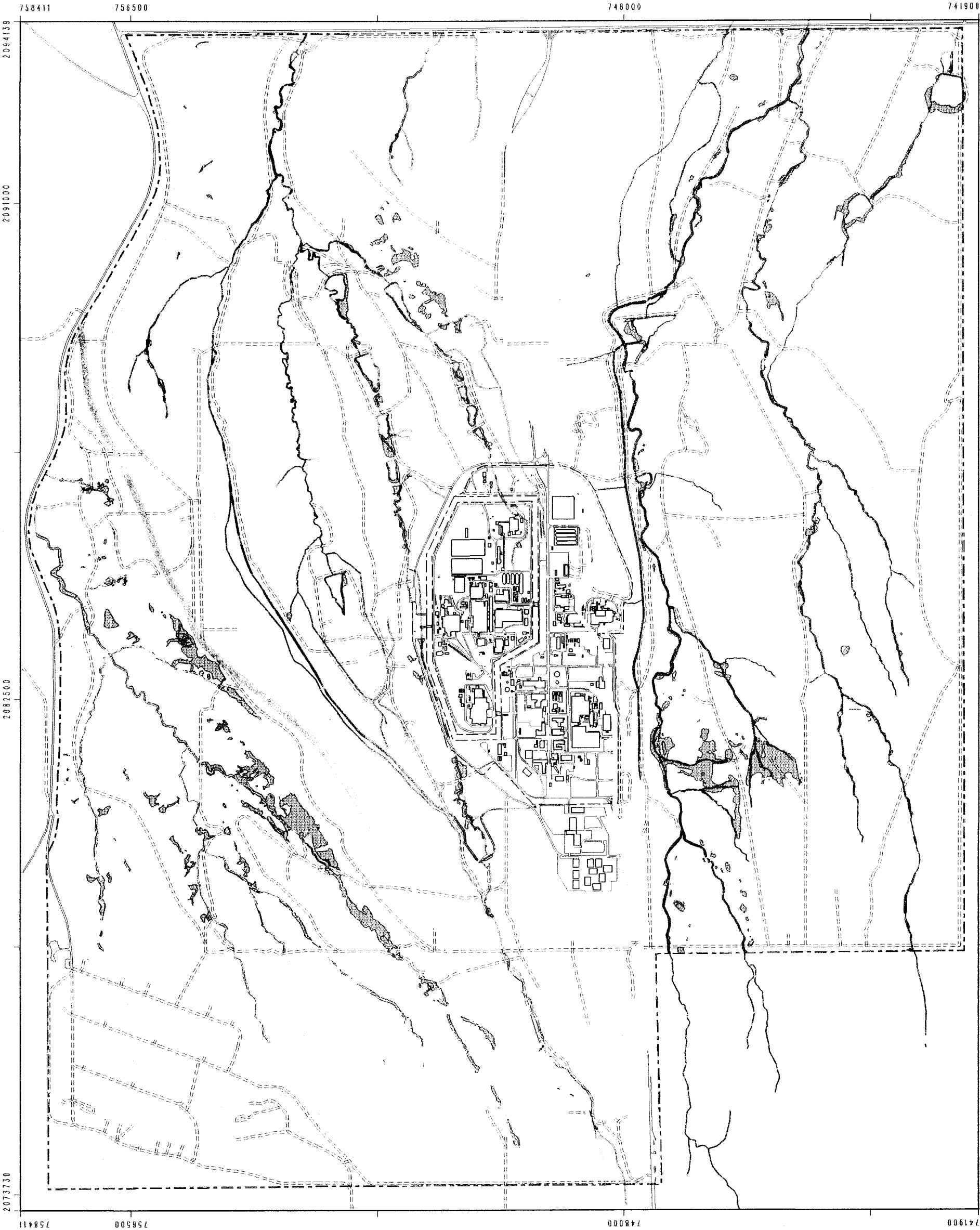
U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

Wetlands

September 1995

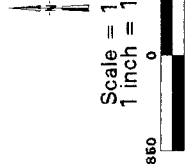
Figure N2-6



EXPLANATION

- Records of Preble's Meadow Jumping Mouse
- Probable Habitat
- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds
- Buildings

Modified from: DOE 1995c



Scale = 1 : 20400
1 inch = 1700 feet

Datum: NAD27
Colorado Central Zone
State Plane Coordinate System

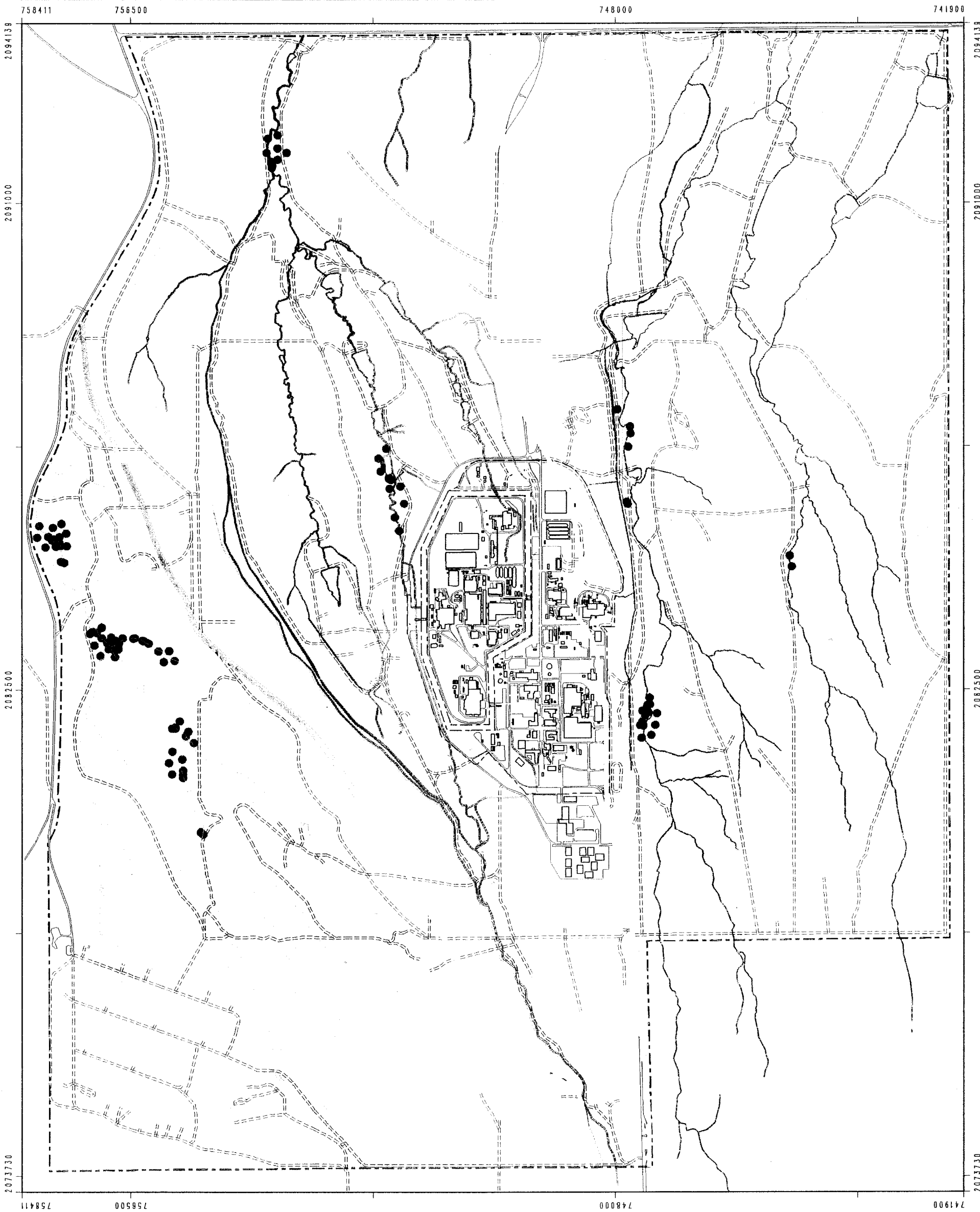
U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

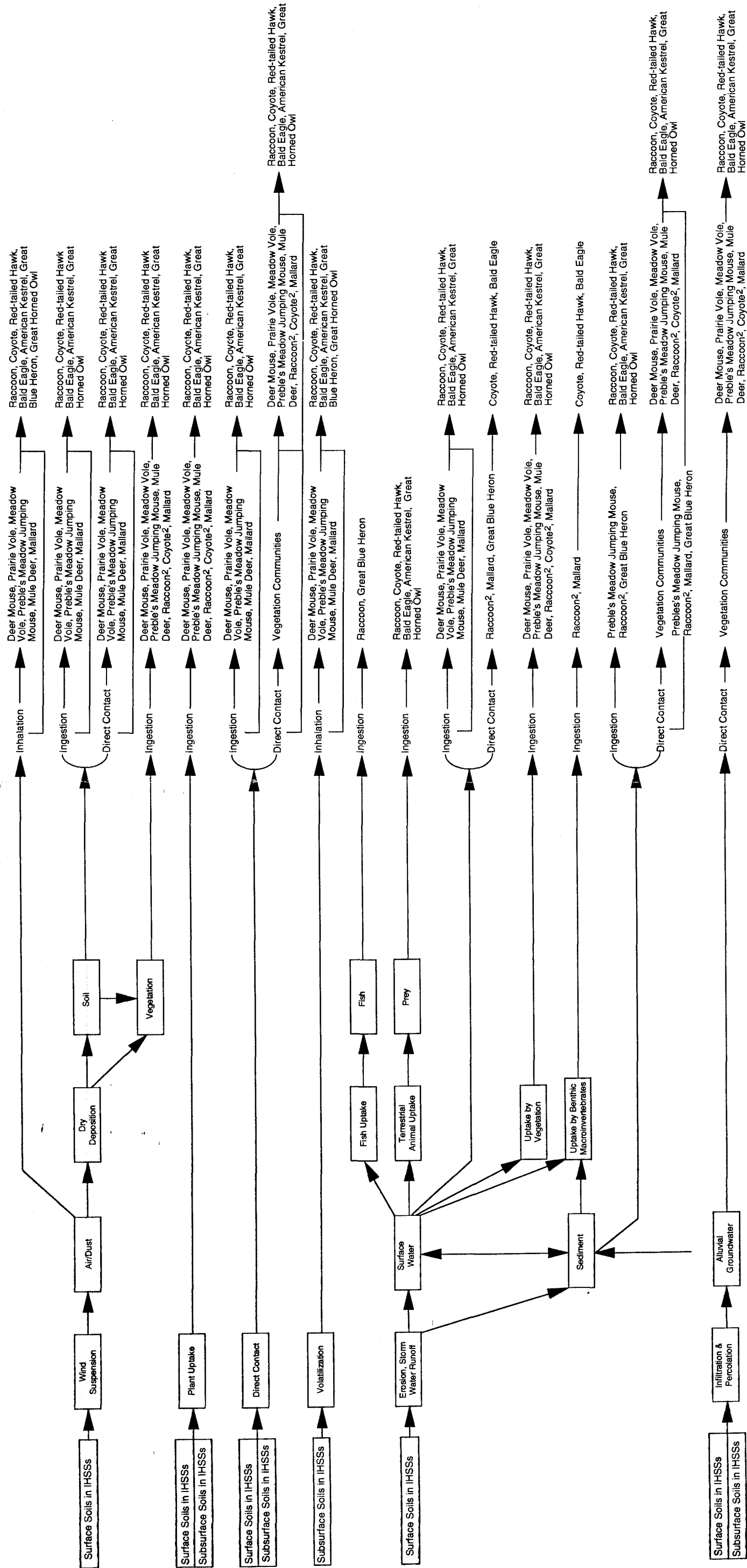
Capture Locations and
Probable Habitat of
Preble's Meadow
Jumping Mouse at RFETS
(*Zapus hudsonius preblei*)

September 1995

Figure N2-7



Primary Release Mechanism Secondary Source Secondary Release Mechanism Exposure Point Exposure Route KEY RECEPTORS¹



¹ A subset of wildlife species representing trophic and functional groups may be included in exposure estimations.
² Not typically a prey species

KEY RECEPTORS¹

Exposure Route

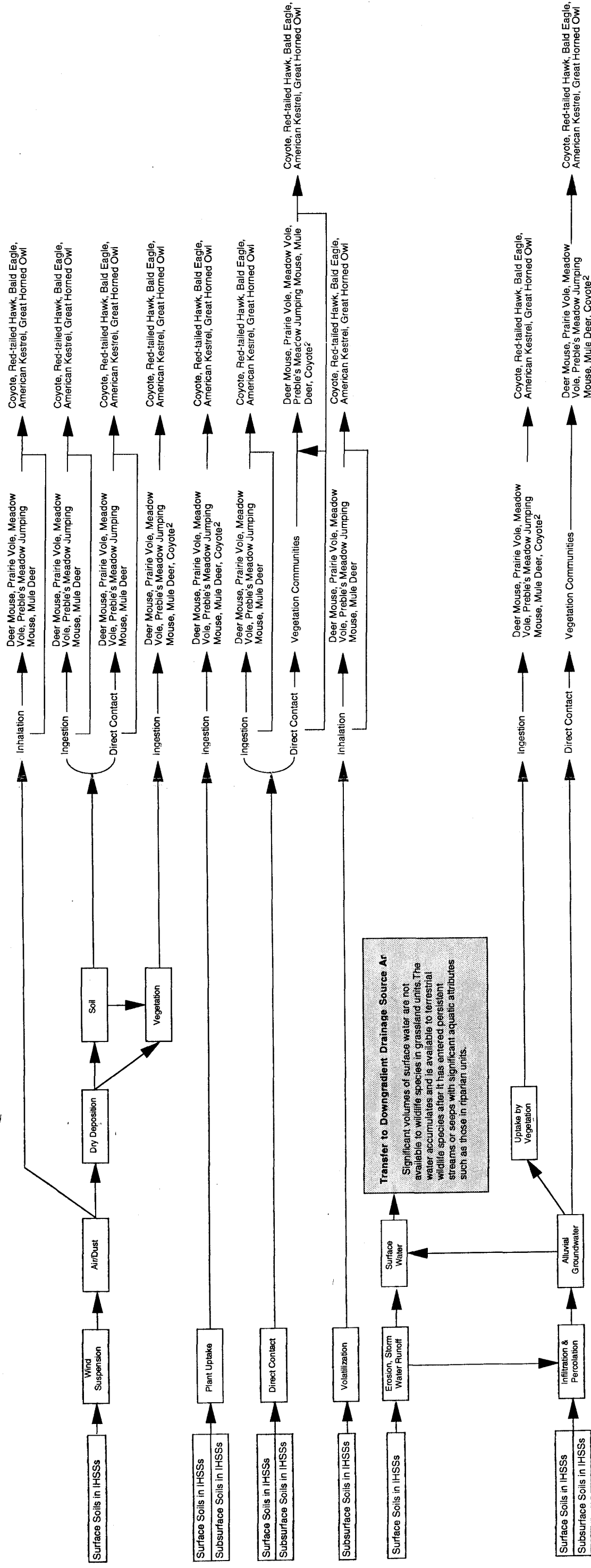
Exposure Point

Secondary Release Mechanism

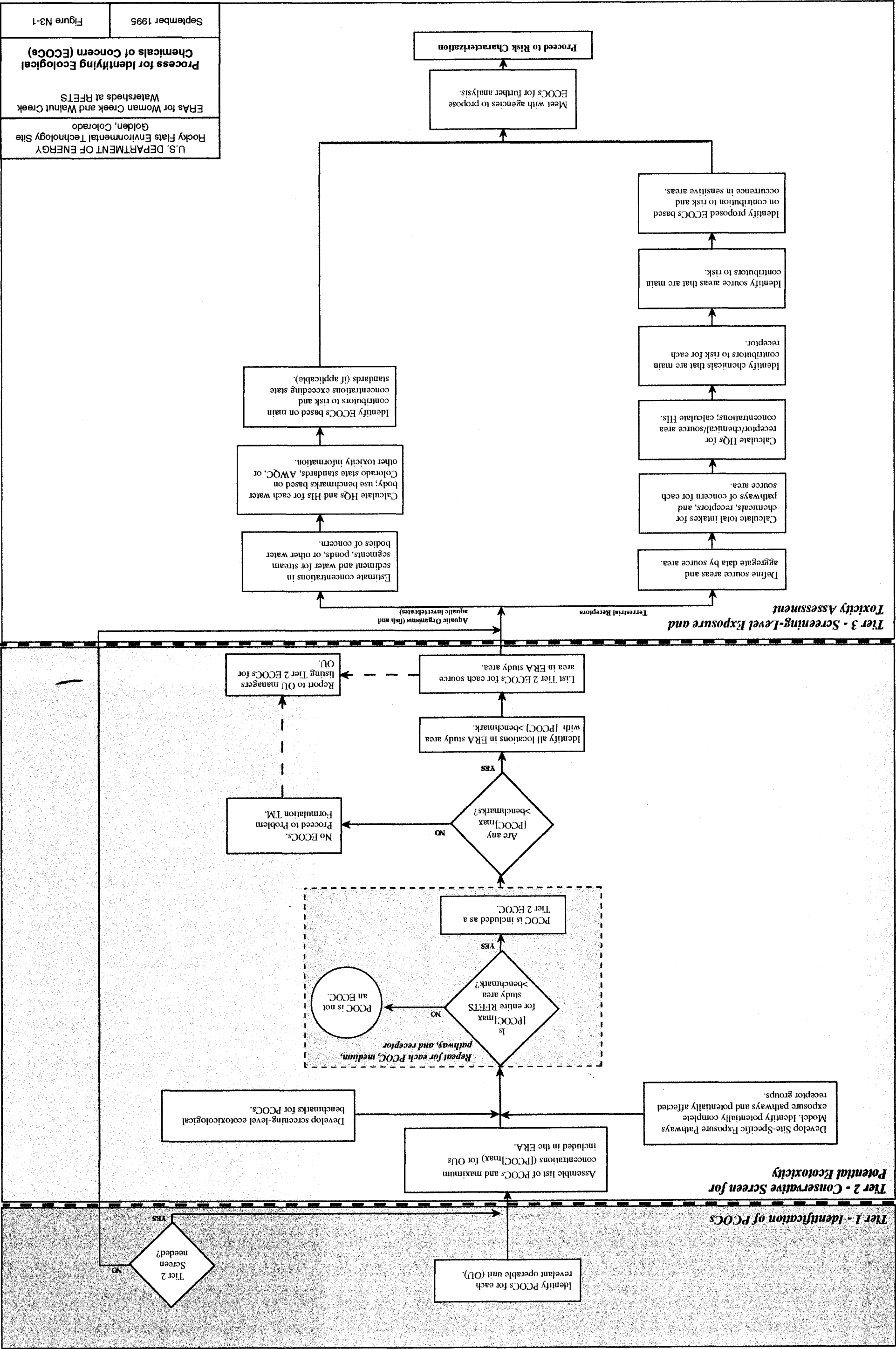
Secondary Source

Primary Release Mechanism

Primary Source



¹ A subset of wildlife species representing trophic and functional groups may be included in exposure estimations
² Not typically a prey species



EXPLANATION

- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds
- Buildings
- Operable Unit 1
881 Hillside
- Operable Unit 2
903 Pad, Mound, and East Trenches
- Operable Unit 4
Solar Ponds
- Operable Unit 5
Woman Creek
- Operable Unit 6
Walnut Creek
- Operable Unit 7
Present Landfill
- Operable Unit 10
Other Outside Closures
- Operable Unit 11
West Spray Field
- ERA Source Areas



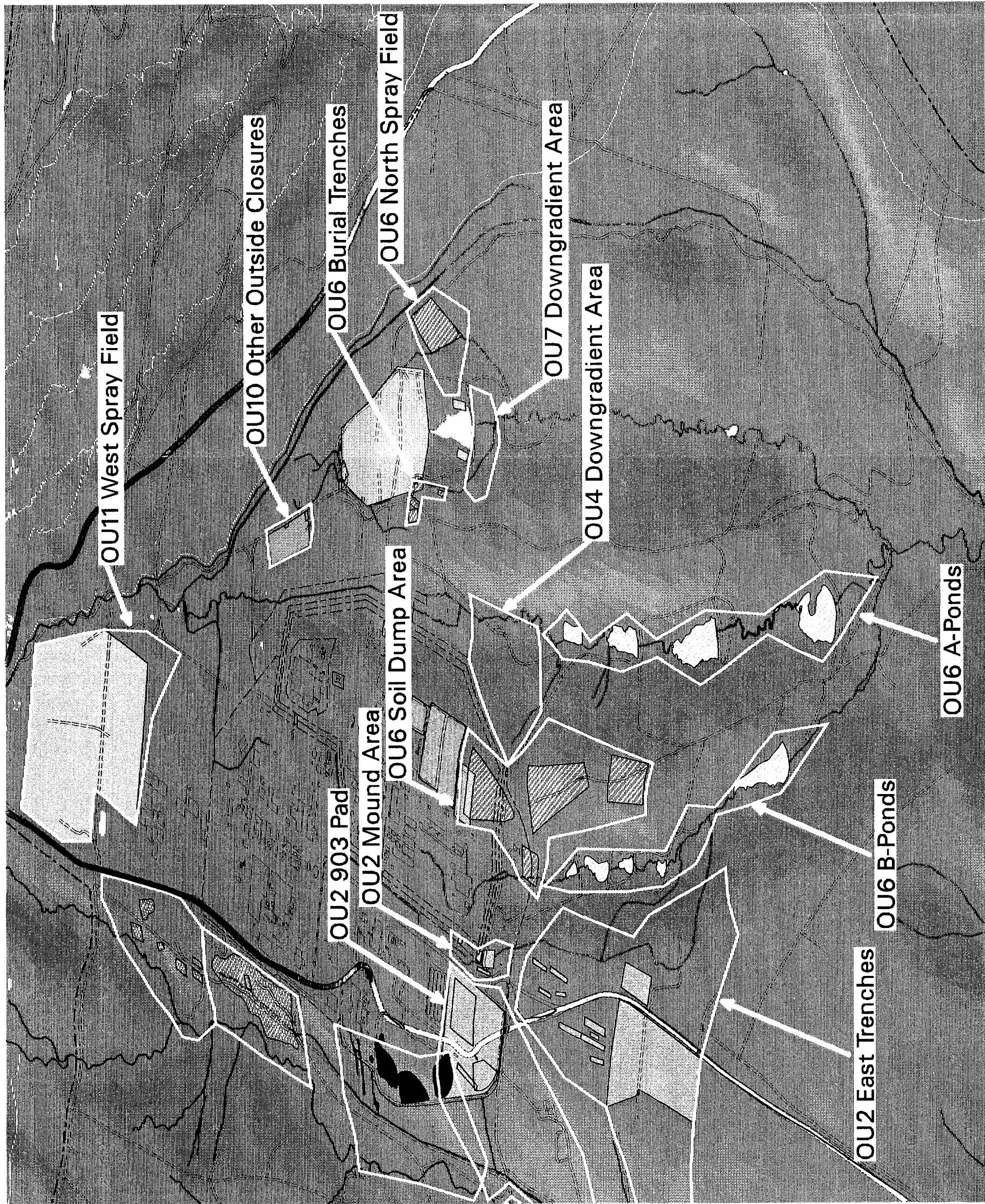
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Golden, Colorado

ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

ERA Source Areas
in
Walnut Creek Watershed

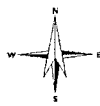
September 1995

Figure N3-2



EXPLANATION

- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds
- Buildings
- Operable Unit 1
881 Hillside
- Operable Unit 2
903 Pad, Mound, and East Trenches
- Operable Unit 4
Solar Ponds
- Operable Unit 5
Woman Creek
- Operable Unit 6
Walnut Creek
- Operable Unit 10
Other Outside Closures
- Operable Unit 11
West Spray Field
- ERA Source Areas



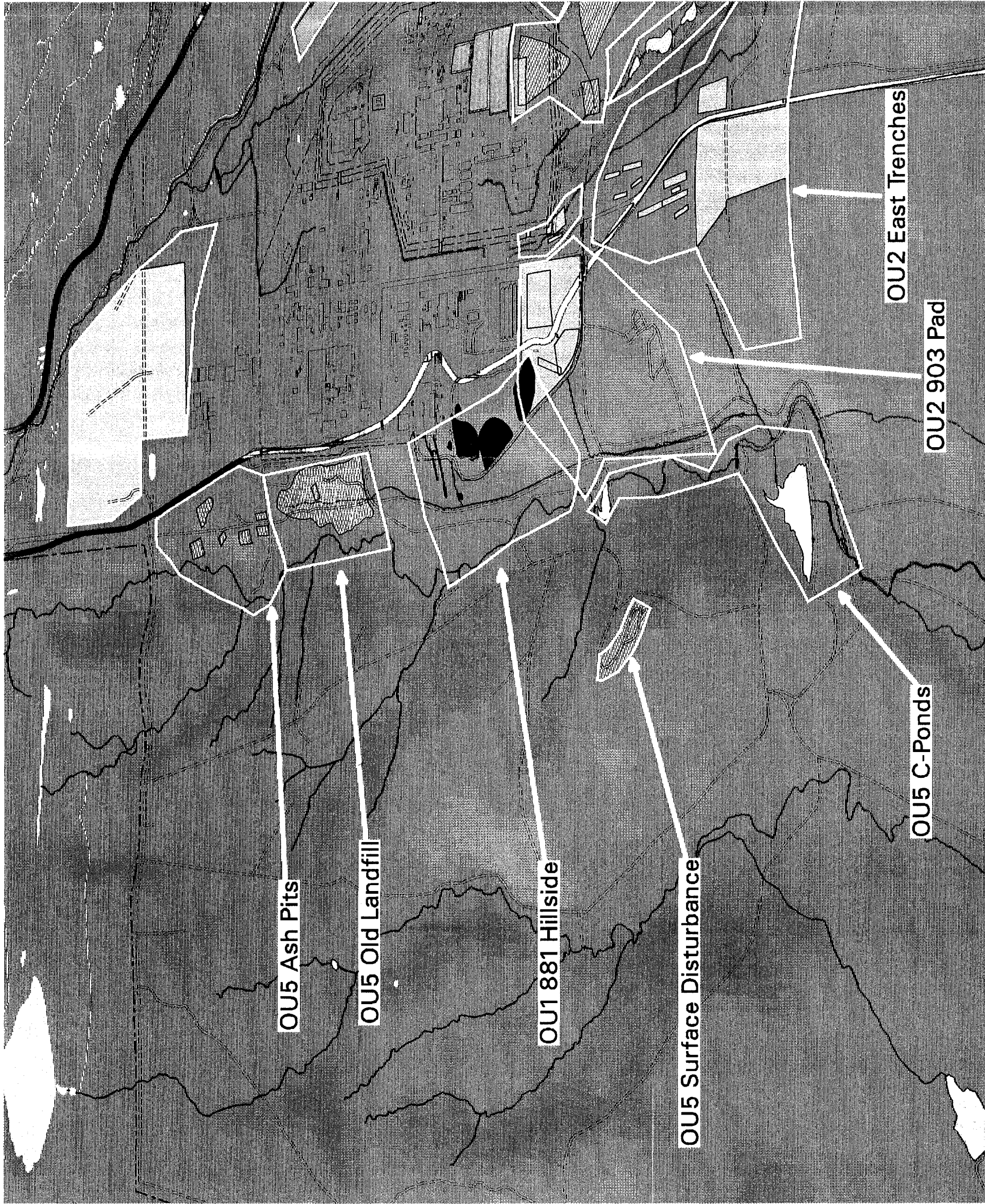
U.S. Department of Energy
Rocky Flats Environmental Technology Site
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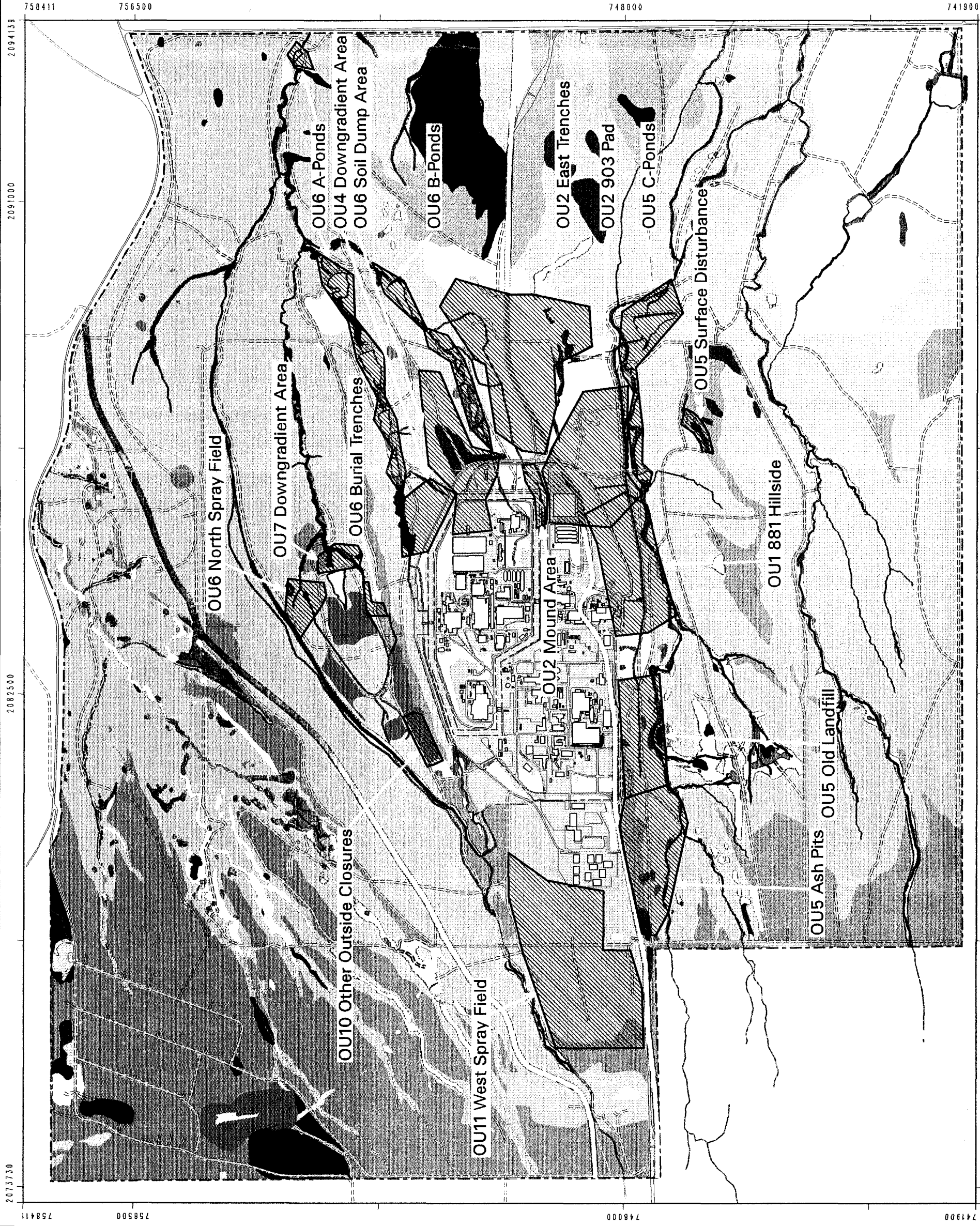
ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

ERA Source Areas
in
Woman Creek Watershed

September 1995

Figure N3-3





EXPLANATION

- Wet Meadow
- Short Marsh
- Tall Marsh
- Riparian Woodland
- Ponderosa Pine Woodland
- Tree Plantings
- Riparian Shrub
- Short Upland Shrub
- Tall Upland Shrub
- Short Grassland
- Mesic Mixed Grassland
- Xeric Mixed Grassland
- Reclaimed Grassland
- Disturbed Area - Annual Grass/Forb
- Disturbed Area - Disturbed/Barren Land
- Disturbed Area - Developed Areas
- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds
- Buildings
- Source Areas

Scale = 1 : 20400
1 inch = 1700 feet

Datum: NAD27
Colorado Central Zone
State Plane Coordinate System

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

Vegetation Types
and Source Areas

58411 756500 2094139 2091000 2082500 2073730 758411 756500 748000 741900

OU6 A-Ponds
 OU4 Downgradient Area
 OU6 Soil Dump Area
 OU6 B-Ponds
 OU2 East Trenches
 OU2 903 Pad
 OU5 C-Ponds
 OU5 Surface Disturbance
 OU1 881 Hillside
 OU5 Ash Pits
 OU5 Old Landfill
 OU6 North Spray Field
 OU7 Downgradient Area
 OU6 Burial Trenches
 OU2 Mound Area
 OU10 Other Outside Closures
 OU11 West Spray Field
 OU6 Downgradient Area

Scale = 1 : 20400
1 inch = 1700 feet

U.S. Department of Energy
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Golden, Colorado

ERAs for Walnut Creek and Woman Creek Watersheds at RFETS

September 1995	Figure N3-6
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EXPLANATION

- Records of Preble's Meadow Jumping Mouse
- ▬ Probable Habitat
- ▬ Watershed Boundary
- ▬ Rock Creek Watershed
- ▬ Walnut Creek Watershed
- ▬ Woman Creek Watershed
- ▬ Central Avenue
- ▬ Dirt Roads
- ▬ Canals and Ditches
- ▬ Security Fences
- ▬ Rocky Flats Buffer Zone
- ▬ Lakes and Ponds
- ▬ Buildings
- ▬ Source Areas

Modified from: DOE 1995c

Scale = 1:20400
1 inch = 1700 feet

Datum: NAD27
Colorado Central Zone
State Plane Coordinate System

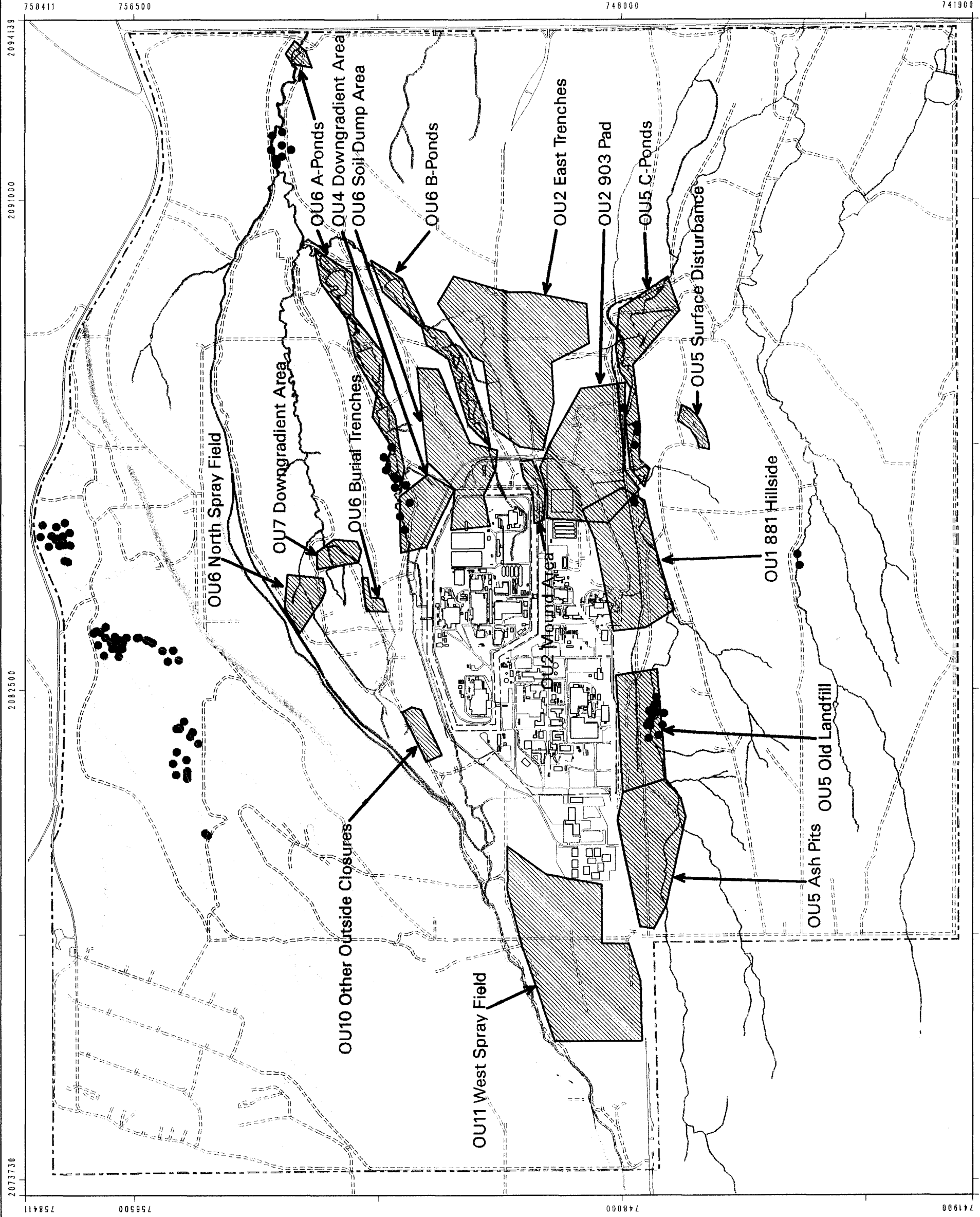
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Golden, Colorado

ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

Probable Habitat of
Preble's Meadow
Jumping Mouse
and ERA Source Areas

September 1995

Figure N3-7



2094139

2091000

2082500

2073730

Waterbody Boundary
Rock Creek Watershed
Walnut Creek Watershed
Woman Creek Watershed
Canals and Ditches
Security Fences
Rocky Flats Buffer Zone
Lakes and Ponds
Source Areas

American Kestrel

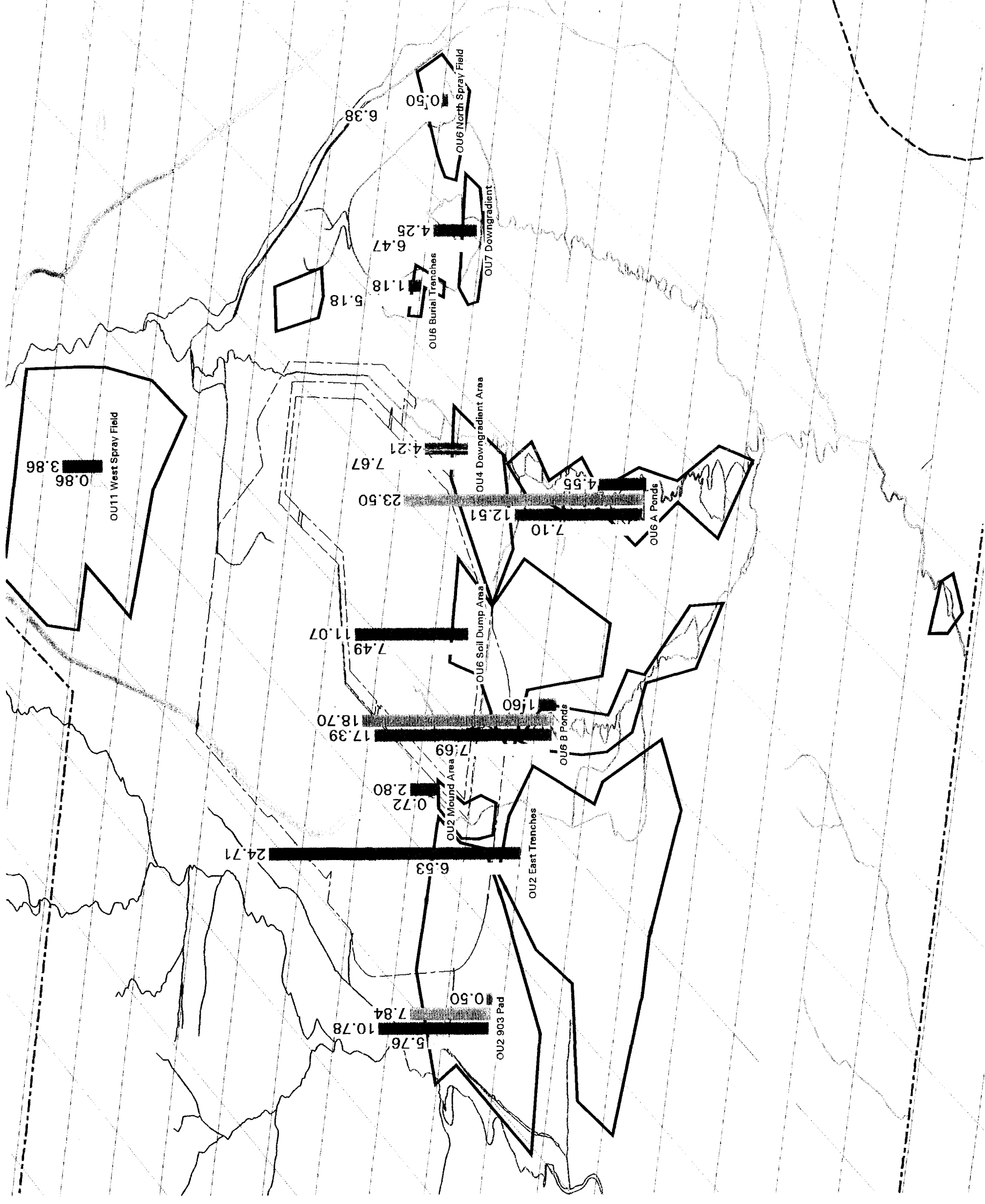
Mallard



ERAs for Walnut Creek and Woman Creek Watersheds at RFETS

Hazard Indices for Walnut Creek Watershed

Figure N3-10



EXPLANATION

- Watershed Boundary
- Rock Creek Watershed
- Walnut Creek Watershed
- Woman Creek Watershed
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds
- Source Areas

Preble's Meadow Jumping Mouse

American Kestrel

Great Blue Heron

Mallard



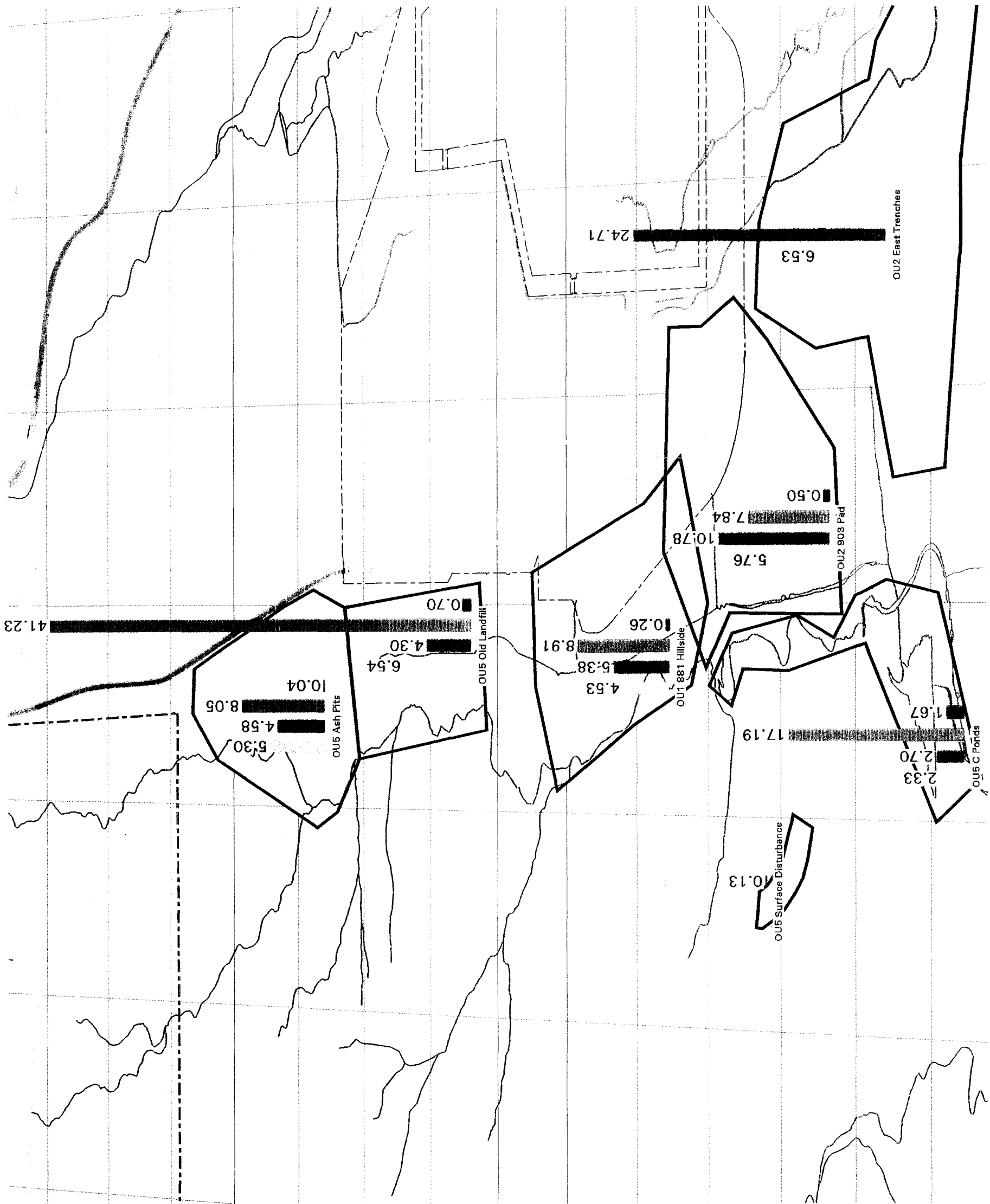
U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

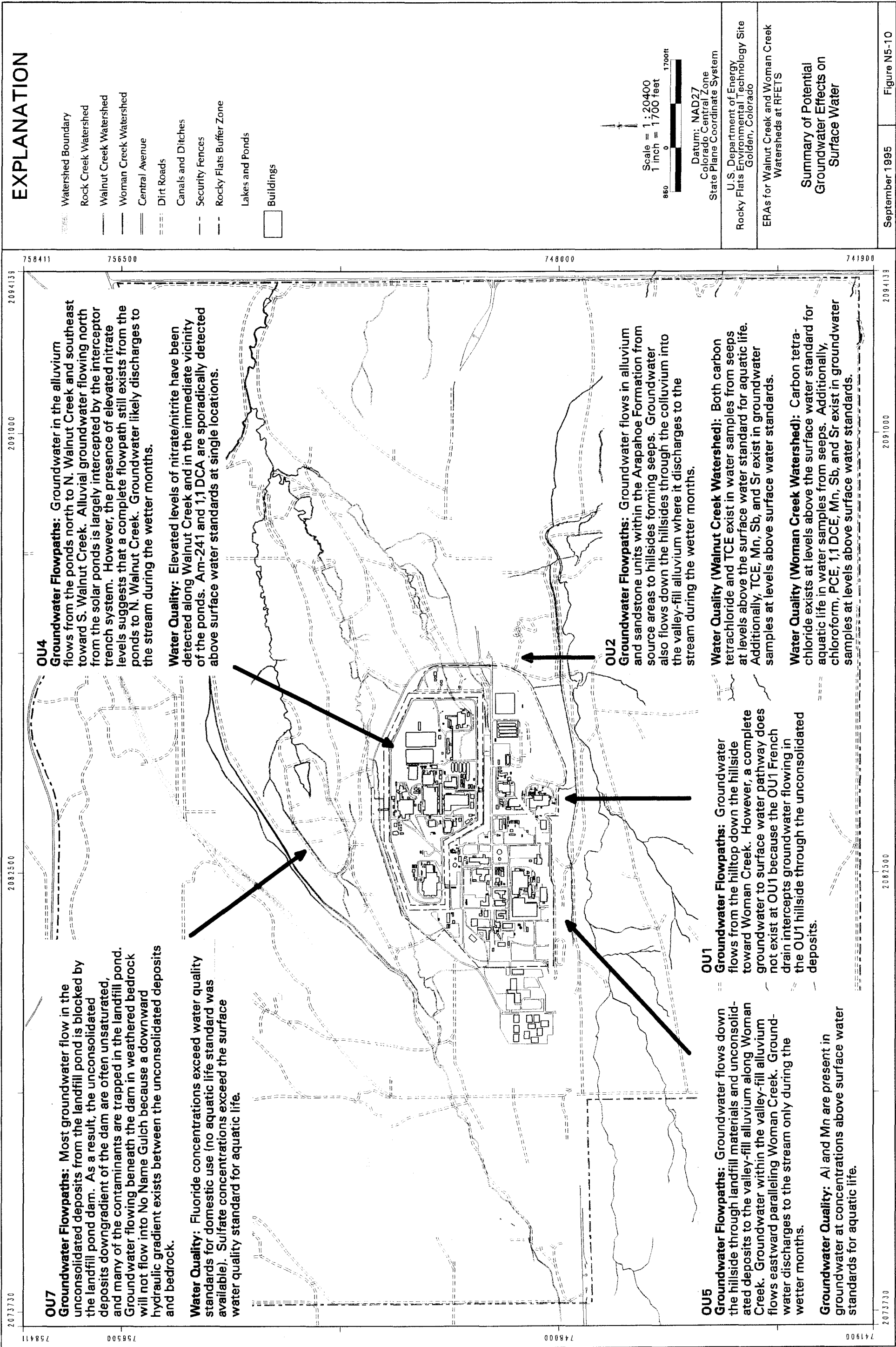
ERAs for Walnut Creek and Woman Creek
Watersheds at RFEYS

Hazard Indices
for
Woman Creek Watershed

September 1995

Figure N3-11





[illegible]

Figure N5-14

EXPLANATION

- Watershed Boundary
- Walnut Creek Watershed
- Woman Creek Watershed
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone

Lakes and Ponds

Source Areas

Buildings

- Small Mammal Sample Locations
- Surficial Soil Sample Locations

Scale = 1:10200
1 inch = 850 feet

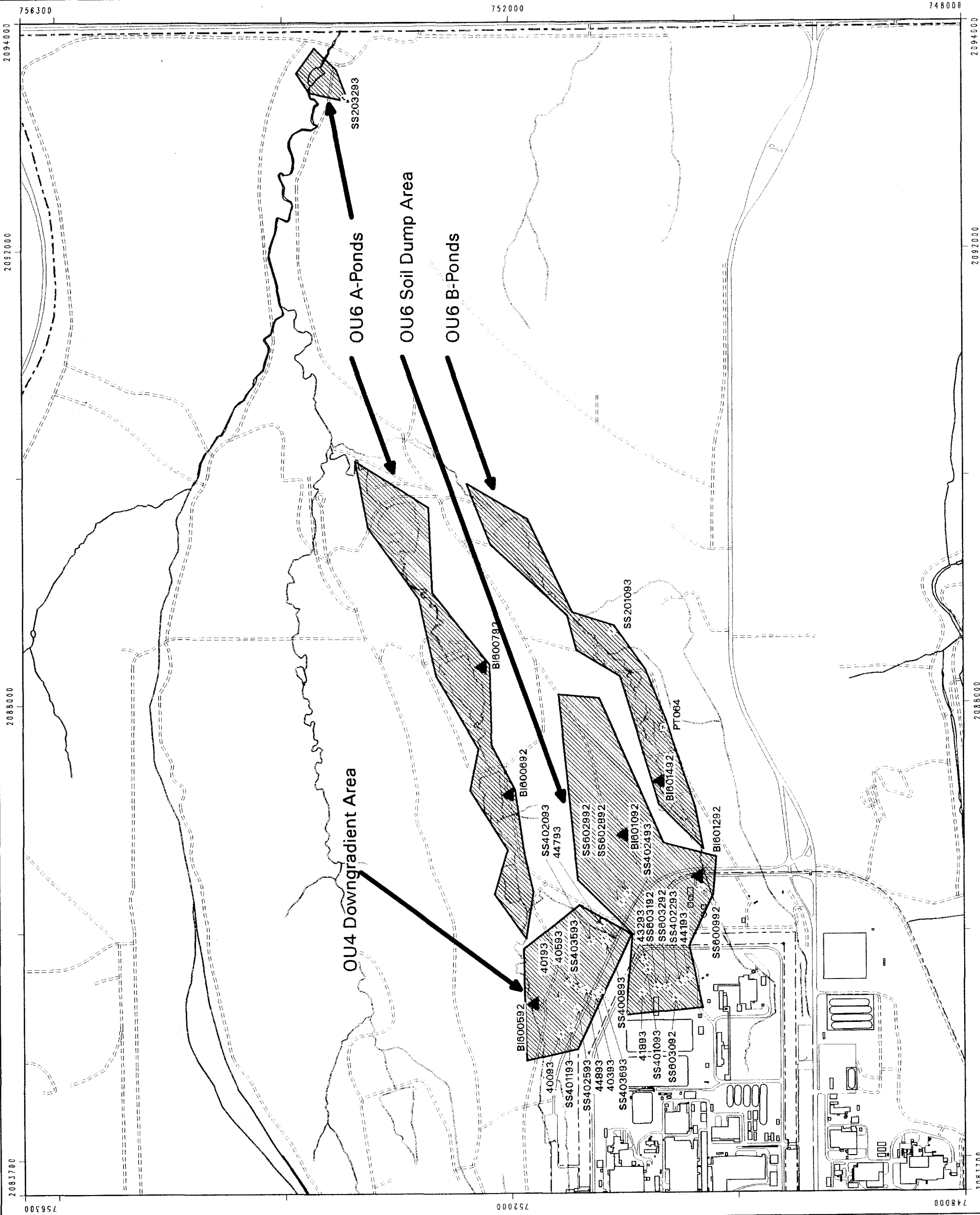
Datum: NAD27
Colorado Central Zone
State Plane Coordinate System

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Golden, Colorado

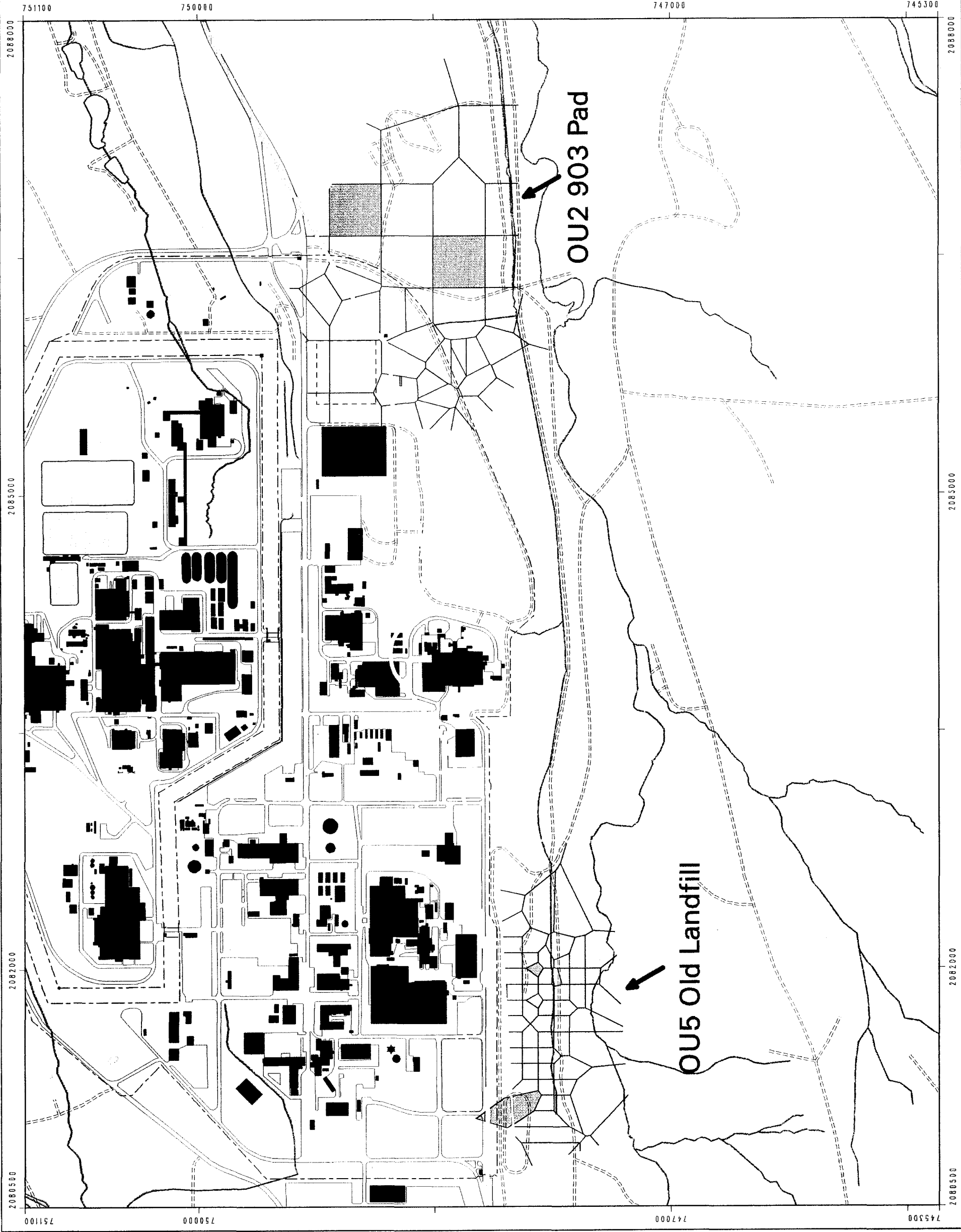
ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS
**OU4/OU6 Source Areas and
Small Mammal and
Surficial Soil
Sampling Locations**

September 1995

Figure N5-15





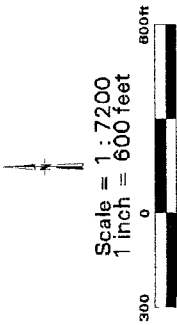


EXPLANATION

- Areas Where Surface Soil Radionuclide Concentrations Exceed Toxicity Reference Value (TRV)
- Watershed Boundary
- Walnut Creek Watershed
- Woman Creek Watershed
- Central Avenue
- Dirt Roads
- Canals and Ditches
- Security Fences
- Rocky Flats Buffer Zone
- Lakes and Ponds
- Buildings
- Source Areas
- Preble's Meadow Jumping Mouse Probable Habitat
- 903 Pad

NOTE: Thiessen polygons used to denote approximate area where radionuclide concentrations exceed the TRV.

Polygons outside of source areas are not shown unless radionuclide concentrations exceed TRV.



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ERAs for Walnut Creek and Woman Creek
Watersheds at RFETS

Surface Soil Radionuclide
Concentrations Exceeding TRV